IN THE UNITED STATES DISTRICT COURT

FOR THE NORTHERN DISTRICT OF OKLAHOMA

STATE OF OKLAHOMA, ex rel.)
W.A. DREW EDMONDSON, in his)
capacity as ATTORNEY GENERAL)
OF THE STATE OF OKLAHOMA,)
et al.)
)
Plaintiffs,)
vs.)CASE NO. 05-329-GKF-PJC
)
TYSON FOODS, INC., et al.,)
)
)
Defendants.)

TRANSCRIPT OF NONJURY TRIAL PROCEEDINGS
JANUARY 25, 2010
BEFORE GREGORY K. FRIZZELL, U.S. DISTRICT JUDGE
VOLUME 98, P.M. SESSION

APPEARANCES:

For the Plaintiffs: MR. W.A. DREW EDMONDSON
Attorney General
MS. KELLY FOSTER
Assistant Attorney General
State of Oklahoma
313 N.E. 21st St.
Oklahoma City, OK 73105

(APPEARANCES CONTINUED)

MR. M. DAVID RIGGS
MR. DAVID P. PAGE
MR. RICHARD T. GARREN
Riggs Abney Neal Turpen
Orbison & Lewis
502 W. 6th Street
Tulsa, OK 74119

MR. ROBERT A. NANCE
MS. SHARON GENTRY
Riggs Abney Neal Turpen
Orbison & Lewis
5801 Broadway
Extension 101
Oklahoma City, OK 73118

MR. LOUIS W. BULLOCK
MR. ROBERT BLAKEMORE
Bullock Bullock &
Blakemore
110 W. 7th, Ste 770
Tulsa, OK 74119

MR. FREDERICK C. BAKER
MS. ELIZABETH CLAIRE XIDIS
MS. INGRID MOLL
Motley Rice LLC
28 Bridgeside
P.O. Box 1792
Mount Pleasant, SC 29465

For Tyson Foods:

MR. ROBERT W. GEORGE
Tyson Foods, Inc.
2210 West Oaklawn Drive
Springdale, AR 72701

MR. JAY THOMAS JORGENSEN
MR. THOMAS GREEN
MR. MARK HOPSON
MR. GORDON D. TODD
Sidley Austin LLP
1501 K St. NW
Washington, DC 20005

(APPEARANCES CONTINUED)

For Cargill:
MR. JOHN H. TUCKER
MS. THERESA HILL
Rhodes Hieronymus Jones
Tucker & Gable
100 W. 5th St., Ste 400
Tulsa, OK 74103

MR. DELMAR R. EHRICH
MS. KRISANN KLEIBACKER LEE
MR. BRUCE JONES
Faerge & Benson
90 S. 7th St., Ste 2200
Minnaepolis, MN 54402

For Simmons Foods:
MR. JOHN R. ELROD
MS. VICKI BRONSON
Conner & Winters
211 E. Dickson St.
Fayetteville, AR 72701

For Peterson Farms:
MR. A. SCOTT MCDANIEL
MR. PHILIP HIXON
MS. NICOLE LONGWELL
MR. CRAIG MIRKES
McDaniel Hixon Longwell &
Acord PLLC
320 S. Boston, Ste 700
Tulsa, OK 74103

For George's:
MR. WOODY BASSETT
MR. VINCENT O. CHADICK
MR. JAMES GRAVES
MS. K.C. TUCKER
MR. GARY WEEKS
Bassett Law Firm
P.O. Box 3618
Fayetteville, AR 72702

For Cal-Maine:
MR. ROBERT SANDERS
Young Williams P.A.
P.O. Box 23059
Jackson, MS 39225

MR. ROBERT P. REDEMANN
Perrine McGivern Redemann
Reid Berry & Taylor PLLC
P.O. Box 1710
Tulsa, OK 74101

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JANUARY 25, 2010:

THE COURT: Mr. Bullock.

MR. GEORGE: There are two procedural issues. I'll let Mr. Bullock --

MR. BULLOCK: Thought that it might be helpful to the parties if we had some brief discussion with the court's thoughts as to scheduling of the closing argument on the 11th.

I guess our suggestion would be this: Looking at to get it done in a day, if each side has three hours and then we go 9:00 to 11:30 for the plaintiff's initial closing and with a 15-minute break in there, that's two hours 15 minutes. And then come back after lunch at 1 o'clock, three hours and 15 minutes with a 15-minute break for the defense to respond. That puts you at 4:15, 45 minutes for the response, and we're out of here at 5:00.

THE COURT: Perfect.

Mr. George.

MR. GEORGE: I hadn't heard that specific proposal, so I was looking for affirmation, Your Honor, and I got some sort of timid head nods. I take that as we're generally okay with that.

MR. ELROD: The issue is not going to be dividing time between them and us; it's going to be dividing time between us. But we'll work that out, Judge.

MR. GEORGE: My experience has shown that the way to insulate yourself from that issue is to be the first one to the podium. We're going to go first.

Your Honor, one other procedural issue that I want to raise for the court's consideration, and we'll see if it actually materializes today, but based upon the testimony that Dr. Engel provided in response to and providing some new analysis of Dr. Connolly's work, I would like to request a very limited surrebuttal of about ten minutes, honestly, just to give Dr. Connolly, as opposed to me, a chance to respond.

Of course Dr. Connolly is in the courtroom and heard the testimony in terms of the legal standards the same as the court has applied to rebuttal, and obviously you have discretion in that area.

We think in the interest of making sure that the court gets information that's useful, it would be more productive to allow a couple of

questions of Dr. Connolly to respond to what he's heard.

The reason I raise it now is Dr. Connolly has a commitment tomorrow that he has to make in another state. And if we were going to be able to put him on for some limited surrebuttal, it would need to happen after Dr. Engel steps down from the stand today. And that would interrupt to some extent perhaps the State's rebuttal case, so I wanted to raise it.

I've mentioned it to Mr. Page. And I know he was caucusing with his group, and I'm not sure what conclusion they've come to, but I wanted to at least raise it with the court.

THE COURT: Any conclusion, Mr. Page?

MR. PAGE: Yes. I think if it's all right, Your Honor, Ms. Moll will respond.

THE COURT: Very well.

MS. MOLL: Good afternoon, Judge Frizzell. As an initial matter, we oppose defendant's request for surrebuttal. They can request surrebuttal at the end of our rebuttal case. We're still in our rebuttal case, and we have Dr. Wells, who is here and is ready to go, so I think Mr. George's request is premature.

As a matter of timing, while I respect the schedule of Dr. Connolly, I also respect the schedule of Dr. Wells, and he is from Oregon. He has many obligations in Oregon tomorrow that he would like to be able to satisfy. I am told that he has a class tomorrow, he has other administrative meetings and other appointments in the afternoon that he would like to meet. And so I don't know why we should, in all candor, respect Dr. Connolly's schedule over Dr. Wells' when we are in the midst of our rebuttal case. I don't think there's a legitimate reason to disrupt that schedule.

THE COURT: That begs the question. I understood that the State was only going to have two rebuttal witnesses.

MS. MOLL: That's correct.

THE COURT: And it was supposed to be a day and a half. So one would imagine and would have imagined that Wells would go into tomorrow anyway, correct?

MS. MOLL: Well, I think we're all surprised how quickly this morning moved, and we're pleased by it. We didn't want to underestimate the amount of time our rebuttal case did, since we perhaps underestimated the time the trial in our

case in chief took just by a few months.

And so in any event, we were certainly prepared for Dr. Wells to proceed today. And, in fact, I believe he has a plane ticket on the six o'clock if he's able to make it tonight. So we were anticipating being able to put him on today.

THE COURT: That would presuppose that we can get through with the cross-examination of this witness here, given that direct ended at about quarter of noon.

My inclination would be to allow it if it's a ten-minute surrebuttal. I only have two or three questions here relating to Dr. Connolly, so it would be very quick. I don't think it would appreciably cut in. And, obviously, we could extend a bit past five. That's assuming, however, that my twin 13-year-olds' basketball game doesn't start too early. So let's get on with it. Mr. George.

MR. GEORGE: Thank you, Your Honor.

DR. BERNARD ENGEL,

having been previously duly sworn, was called as a witness and testified as follows:

CONTINUED CROSS-EXAMINATION

BY MR. GEORGE:

Q. Good afternoon, Dr. Engel.

A. Good afternoon.
Q. Dr. Engel, you talked quite a bit during your direct examination about your routing model. And, in fact, one or two of the demonstratives that were used in your testimony were screen shots of a spreadsheet that encompasses your routing model; is that correct?
A. Yes.
Q. Just so the record is clear, Dr. Engel, what we're referring to as your routing model is actually a formula that is set out in an Excel spreadsheet, correct?
A. Well, the formula was developed, and then it was implemented inside an Excel spreadsheet, so the model is certainly more than just an Excel spreadsheet.
Q. Didn't mean to oversimplify. Let me ask the question more basically. If one wanted to understand the way in which your routing model works and to actually see how these coefficients interplay with the results, the best place to go to evaluate and get a sense of that would be the spreadsheets, correct?
A. Yes. So in the spreadsheets, one could see how the equation operated.

Q. Okay. Well, let's do that, if we might. I want to show the court what this spreadsheet looks like and go through it in a little bit of detail to have you explain and create a record as to how this works.

Could we pull up a native version of the spreadsheet, which is Defendants' Joint Exhibit 8154. Hopefully it's on the screen in front of you, Doctor. Is it?

A. Yes.

Q. And you'll see at the top that this spreadsheet is identified as P_model_10_15.xls. Do you see that?

A. Actually, it's kind of tough to see on this monitor.

Q. You might look at this one, Doctor. It's actually kind of difficult to see on that as well.

MR. GEORGE: Can we reduce the size at all so we can see it on the image? The top part is cut off.

Q. (By Mr. George) Can you see the title now, Doctor?

A. Yes.

Q. Did I read it correctly in terms of the file name for this model?

A. Yes.
Q. Okay. And you recognize that file name, don't you?
A. I believe I do.
Q. This is the Excel spreadsheet that you generated in connection with the errata that you produced in October of 2008; is that right?
A. This does seem to be that spreadsheet, yes.
Q. And for the record, this is also the spreadsheet that Dr. Bierman performed his sensitivity test on where he changed certain values and evaluated the effect of that; is that right?
A. I'm not sure I would characterize it as a sensitivity test, but this does seem to be the spreadsheet that Dr. Bierman changed coefficients in and changed the model in.
Q. And this particular spreadsheet and the charts that you see popping up on it show what you've referred to as your calibration and validation for the period of 1998 through 2006, does it not?
A. You're referring to the figure -- I guess the couple figures that are partially displayed?
Q. Correct.
A. Well, let's see, I believe those would be part of the calibration validation plots. I'm not sure

if those were final ones. I can't see all the details here.

Q. Really my question was more general than that. Can you confirm for us that the spreadsheet that we have on the screen is the spreadsheet that relates to your calibration and validation for the period of 1996 through 2006?

MR. PAGE: Your Honor, all we could see is part of the spreadsheet, so I would object because he's characterizing the whole spreadsheet, and all we can see is part of it.

THE COURT: Overruled. I think we're being overly technical.

Is this part of that spreadsheet?

THE WITNESS: Yes, this is certainly part of the spreadsheet.

Q. (By Mr. George) Doctor, I just want to create a record here and illuminate how this works a little bit. The spreadsheet is divided by subwatershed, correct?

A. Yes.

Q. And if you look at columns B through H of the spreadsheet, are those for the Illinois River subwatershed?

A. Yes, they would be.

Q. Let's focus on that portion for a moment. If we look at column B, do you see "River P" as the caption of the column B?
A. Yes.
Q. And that is GLEAMS output plus the wastewater treatment plant loads to the river; is that right?
A. Yes, that would be correct.
Q. If we go over to column C, the heading is "Q," and then in parentheses, "CFS," do you see that?
A. Yes.
Q. What is that?
A. So that would be the USGS flow on each of these dates at Tahlequah, the average flow for that date.
Q. Then if we move over to column D, the heading there is "LOADEST," and that is the observed phosphorus loads to the lake at the gauging station computed by you using LOADEST equation, correct?
A. Yes, that would be a LOADEST calculation. I don't recall which of the LOADEST calculations this one might be.
Q. Okay. Just so the record is clear, we've referred to these LOADEST products as observed loads, but they're not actual observed loads. They're an estimation based upon a regression analysis; is that right?

A. They would be a calculation based on observed flow and observed concentrations.
Q. Can we go over to column E. Can you see that on your screen, Doctor? Do you see column E is entitled "Accumulated P"?
A. Yes.
Q. And in that column, we have the difference between the phosphorus that you've put into the routing model and the phosphorus that's been routed by your equation downstream to the gauging station, correct?
A. Yes, it would be.
Q. Now, column F is entitled "P to Lake," do you see that?
A. Yes.
Q. And the data that appears there is the prediction of the phosphorus output to Lake Tenkiller that is calculated using your routing equation, correct?
A. Correct.
Q. Now, if we go over to columns G and H, and if we look in rows 3 through 5, do you see the values for your coefficients A, B and C?
A. Yes.
Q. And for the record, could you read what those

values are?
A. Looks like A is 0.1. B looks like there are a number of zeros here, then 347. Do you want me to get the specific value?
Q. I tell you, I counted a decimal point, six zeros, then 347. Do you agree with that?
A. Looks like six zeros 347, yes.
Q. Then what about C?
A. And C is 1.05 times 10 to the minus 10.
Q. That would be the same thing as a decimal point, nine zeros, and then 015, right?
A. Yes, it would be.
Q. At the top of column F, it says A plus B times P times Q plus C times P times Q^2. Do you see that?
A. Yes.
Q. That's your routing equation, right?
A. That will be the form of the routing model, yes.
Q. And if we go over to cell F5, we can see the model is applying that equation to generate the P to lake values, right?
A. Yes.
Q. And you'll see there -- you see where the formula is shown at the top of cell F5 up in the window?

A. Yes.

Q. When you click on a cell -- I had to learn this. I'm sure everybody else knows it -- but the formula actually shows up at the top of Excel; is that right?

A. Right.

Q. Okay. And, Doctor, that formula -- I apologize. Once we get these numbers behind us, it will be a little easier. The formula for that particular cell is H3, and that's a reference to the value that is reported in cell H3, right?

A. Correct.

Q. The same format applies throughout. These are references to cell values; is that right?

A. Yes.

Q. Okay. So the formula there, for the benefit of the record, is H3 plus H4 times C5 times E5 plus H5 times $C5^2$ times E5. Did I read that correctly?

A. Yes.

Q. That's the same routing formula that we just discussed, isn't it? It just substitutes the cell values in place of the variables that we saw on the screen earlier?

A. Yes. It picks up the specific coefficient values.

Q. Okay. So if we wanted to break it down, for example, H3 in this formula is coefficient A, right?
A. Yes.
Q. And H4 is coefficient B; is that right?
A. Yes, it would be.
Q. Okay. And C5 is Q, which is flow; is that right?
A. So it would be -- yes, flow on that specific day.
Q. And then E5 is accumulated P; is that right?
A. Correct.
Q. And H5 is the coefficient C?
A. H5 would be C, yes.
Q. Then C5 is flow squared, right?
A. C5 is flow in the model. Implementation, it's flow squared, so that cell is squared.
Q. Lastly, cell E5 is accumulated P again, right?
A. Accumulated P on that day.
Q. Doctor, your GLEAMS plus your wastewater treatment plant phosphorus input loads that we've been hearing about are not part of the actual routing equation that you identify in your report, are they?
A. They would be certainly inputs into the routing model, yes.

Q. If we look at the routing equation -- and we can put it back up if we need to -- your GLEAMS predictions, that's the nonpoint source loads, and your wastewater treatment plant inputs are not one of the variables in that routing equation, right?

A. No, they don't show up in the routing equation.

Q. Instead, the routing equation calculates the phosphorus to lake as a function of flow, accumulated phosphorus and the coefficients; is that right?

A. Yes.

Q. Okay. Your phosphorus inputs from GLEAMS and from the wastewater treatment plants, they arrive in your routing model in the accumulated P column, column E, right?

A. Well, they -- so I guess they show up in column B, and then they're summed to get the accumulated phosphorus as the implementation of that.

Q. That sum for the accumulated phosphorus is in column E, correct?

A. Yes, it would be column E.

Q. Okay. And the spreadsheet calculates accumulated phosphorus for each day by adding the new phosphorus to the river and subtracting the phosphorus to the lake calculated by your equation;

is that right?
A. Yes.
Q. Okay. Now, your routing model on this spreadsheet assumes that all phosphorus predicted by GLEAMS is running off of the edge of fields reaches the rivers that are represented by your spreadsheet; is that right?
A. Well, the -- so the spreadsheet --
Q. Can you answer that question, please? Do I have that right?
MR. PAGE: Objection, Your Honor, I think the witness was attempting to answer the question.
THE COURT: Well, if you could direct yourself to this specific question.
Q. (By Mr. George) Do you want to try it again? Do you need the question again?
A. Please.
Q. Sure. Doctor, the routing model that's embodied in this spreadsheet assumes that all phosphorus predicted by GLEAMS as running off of the edge of fields -- that's the world defined by GLEAMS -- reaches the rivers that are represented by this routing model spreadsheet, correct?
A. Not exactly. If I could explain, I'll better describe what's really happening.

Q. Let me ask another question first, and I will give you the chance to explain, Doctor. Is there any process between the routing model where these loads show up, the nonpoint source loads, and the edge-of-field predictions by GLEAMS that reduces the amount of phosphorus that is predicted running off the field that finds its way into your spreadsheet?
A. No, there's not a reduction there.
Q. Now, you wanted to explain something, and I promised to give you the opportunity. So go ahead.
A. I was just going to explain that although this is labeled Illinois River, it's the streams and channels and the Illinois River, so it really represents the stream and channel network that does extend to the edge of fields.
Q. But once again, the predictions from GLEAMS in terms of runoff at the edge of the fields, the sum total of all of those phosphorus predictions find their way into your routing model, which you describe as representing the streams and river network in the Illinois River, right?
A. Yes.
Q. Now, this accumulated P in column E, it is sort of a phosphorus bank, right?
A. Sorry, in column E again?

Q. Yes, sir.
A. Yes, so this -- that would be a good description. It's essentially a bank account balance of phosphorus in the stream and river network system.
Q. Let's look at the charts. You see there's some charts and graphs that are shown in this spreadsheet. These charts represent your regression analysis; is that right? Do you see the six -- or nine charts, I believe, that are on there?
A. Yes.
Q. And the regressions compare the predicted loads generated by the formula we've been discussing, your routing model, shown in column F, P to lake, with the observed loads set out in column D which are calculated LOADEST loads, right?
MR. PAGE: Your Honor, I object. We did not review any of these R^2 coefficients as part of the rebuttal, so this is beyond the scope.
MR. GEORGE: Your Honor, this witness was called to rebut the testimony of Dr. Bierman regarding the application of this model and how it affects the reliability, and there has been a bit of a mischaracterization going on as to what Dr. Bierman's criticism was related to what

Dr. Engel has testified today. But Dr. Engel has very clearly shown the court copies of this routing model spreadsheet, and I think it's appropriate for us to explore those.

THE COURT: I believe it's within the scope. Overruled.

Q. (By Mr. George) I don't know if we had an answer to that question before the objection. Dr. Engel, did you answer it?

A. Don't know that I did. I've forgotten the question if I didn't.

Q. Let's try it again, Doctor. The regressions that are shown in these charts compare the predicted loads generated by the formula, your routing model, shown in column F, which is P to lake, with the observed loads set out in column D, which are the calculated LOADEST loads, right?

A. So I guess the figures on the left would depict that, yes.

Q. Do the figures on the right not depict that?

A. I believe the figures on the right depict similar columns for Barren Fork and Caney Creek, if I recall correctly.

Q. As a matter of navigation here in the spreadsheet, these tables are arranged in vertical

order; is that right? So the three on the left relate to the Illinois River subwatershed, the three in the middle relate to Barren Fork, and the three on the right relate to Caney Creek; is that right?
A. I believe that's correct.
Q. Now, the top one there, the top left, if you will, is the regression analysis making that comparison for the entire period of 1998 through 2006; is that right?
A. I don't recall -- I'm not recalling which period that one picks up.
Q. You're adept at Excel, I assume, and you understand if we click on this graph, it will show the source data?
A. We can see that by doing that, yes.
Q. Let me ask Mr. Todd to click on it so we can confirm -- you see now that it has highlighted the columns from which it is pulling data. Do you see that?
A. Right. But I still don't know --
Q. Well, it begins in 1999; you agree with that, right?
A. Yes, it appears to.
Q. If we scroll to the bottom of the spreadsheet, we could see where the highlighted column ends; is

that right?
A. It looks like it covers the entire period.
Q. My question was: Will you agree with me that the top one of these panels is the product of your regression analysis for the entire period of 1998 to 2006?
A. Yes.
Q. Okay. And the second one down, the middle one in the left-hand column there, can you confirm for me that that's what you call your validation period comparing predicted versus observed for 2003 through 2006?
A. Again, I'm not recalling the order these were ran, so...
Q. I want you to be confident in your answer, so let's click on that again.
MR. GEORGE: Mr. Todd, could you do that.
Q. (By Mr. George) Do you see where it begins, the period?
A. It looks like it begins in 2003.
Q. Based upon that, can you confirm that this relates to what you call your validation period for 2003 through 2006?
A. That should be that period, yes.
Q. By process of elimination, the third one at the

bottom, can you confirm for me that this relates to what you call your calibration period of 1998 through 2002?
A. So -- yes, that would be the '98 through 2002 data.
Q. And now, each of these three charts show an R^2 value, right?
A. Yes, they do.
Q. Looking at the three for the Illinois River Watershed, can you tell us what the R^2 values were for each of those three charts?
A. Looks like for the first one, it's 0.973. This must be the second -- looks like 0. -- I believe that's a 75. 975, I believe.
Q. Then the third. I show it as .9736; does that look right?
A. Looks like the third is 0.973.
Q. Doctor, those are good R^2 values, aren't they, in the modeling community?
A. Yes, those would be considered good values.
Q. If those R^2 values -- and this, of course, is your work product -- were on the order of, let's say, .1 instead of .9 or .2 instead of .9, you would not have much confidence in this model as a tool for relating phosphorus loads to the river down to the

gauging stations above the lake, would you?
A. I guess I would need to understand the broader circumstances, and not just zero in on that single number. So I would need more context.
Q. Certainly you'd be less comfortable if it was .1 than .9, correct?
A. I would say again that, you know, I would need additional information, additional context to truly understand what was happening here.
Q. Well, let's approach it inversely, if we can. Does it give you some confidence in the reliability of your work that the R^2 values for your model are as high as they are, .97, for example?
A. So, yes, those would provide some level of confidence.
Q. Now, there's one other statistical measure that you report out of this analysis in terms of comparing observed versus predicted loads, and that's something call Nash-Sutcliffe values. You're familiar with that?
A. Yes, I'm familiar.
Q. That's -- Doctor, do I have this right? That's another statistical measure comparing the same two things, observed loads and predicted loads?
A. Yes.

Q. If we scroll out, we can find those -- they're a little harder to find in the spreadsheet. We can find them on your spreadsheet in columns AP through AW in rows 1 through 3. Do you see your Nash-Sutcliffe values?

A. Yes. I believe those are the values here in AQ, AT and AW for each of the gauging stations. That's my recollection.

Q. And for the record, can you provide the court and the record with what those Nash-Sutcliffe values were for this particular model run?

A. Looks like there are -- looks like there are probably two values provided for each gauging station location, so it looks like the values in AQ2 and AQ3 are for the Illinois River at Tahlequah, values being 0.965559 and 0.96128. I don't recall which periods those represent without looking underneath the data again. And then there would be values for Barren Fork in the AT column of 0.82945 and in AT3 of 0.757399. So that would be for Barren Fork.

For Caney Creek would be out in the AW column. Those would be in AW2 and AW3, values would be 0.550431 and 0.650948.

Q. Doctor, once again, the closer those values are

to one, the stronger the relationship or the correlation between observed loads and predicted loads, right?
A. Yes, that would be the case.
Q. Once again, the higher those values, the Nash-Sutcliffe values, the more confidence you place in the model as being useful as a predictive tool, correct?
A. That would generally be the case but, again, there's broader context here as well.
Q. Well, do you recall, Doctor -- I have a sense you're a little hesitant, and I want to explore it a little bit. Do you recall the last time you were in this courtroom and you were asked by Mr. Page about the performance of the model, and you told His Honor that the model performed well because of these high Nash-Sutcliffe and R^2 coefficients or statistics? Do you recall that?
A. Yes.
Q. You're not backing away from that statement, are you?
A. No.
Q. Let's get our head out of the spreadsheet for a moment and talk more conceptually about your routing model. So I think we've established, Doctor, that

your routing model is really an equation, correct?
A. I think we're, again, probably into the semantics issue here that models are made up of equations, so in the simplest form, a model is a single equation.
Q. Let's look at it conceptually. Can we pull up Tyson Demonstrative 382. Give you one in case you need it.
Doctor, I've created what I call a simple schematic to show what your routing model does conceptually. Have you had a chance to look at it?
A. Yes.
Q. Does this schematic show generally the role of the routing model and the overall work you've done in trying to evaluate phosphorus loads in this case?
A. Yes, generally, I guess, again, per the earlier discussion, this P to river is really P to the river stream channel network system. Beyond that, it's a reasonable representation.
Q. As a general matter, what's shown on this schematic, and I think you'll agree is the way this works, is the GLEAMS and the wastewater treatment plant loads that you either estimate or model outside of your routing model come into the spreadsheet that we've been discussing that contains

your routing model, and comes in at the P to river column, and then the routing model over time and amount distributes that down to the three USGS stations, correct?

A. Yes, but let me make -- let me clarify something just a bit there. So the models would be different for each of the three gauging stations, so just not to confuse things here.

Q. Fair point.

A. Those are different -- with different coefficients for each of the three stream and river systems.

Q. But the concept and the way in which the data flows and how it is distributed out works the same in all three subwatersheds, correct?

A. Yes, it would.

Q. Now, in your testimony earlier today, you criticized Dr. Bierman for saying that the routing model we've been referring to as a routing model is an equation and not really a model. Do you recall being asked about that by Mr. Page?

A. Right.

Q. But you agree, do you not, Doctor, that calling that equation a model is a bit strong?

A. I wouldn't agree with that.

Q. Dr. Bierman -- I'm sorry, Dr. Engel, you've been deposed at least twice in this matter, haven't you?

A. Yes.

Q. Do you recall getting a question regarding this model in your deposition and being asked whether this was a routing model or an equation?

A. I don't remember that.

Q. Let's look at your deposition.

MR. GEORGE: Mr. Page, if you want to follow along, we're going to go to page 189, lines 20 through 25.

May I approach, Your Honor? Your Honor, may I approach?

THE COURT: Yes.

Q. (By Mr. George) Doctor, I direct your attention to the question that begins on line 20. And I asked:

"QUESTION: Okay. What is the name of this routing model that you created?"

And then do you see your answer? Your answer was:

"Well, model is probably too strong. So this is simply an equation for which coefficients were identified or values for coefficients were

identified through regression."

Did I ask that question and did you give that answer in your deposition in January of 2008?

A. Looks like that's the case.

Q. Okay. If I understand where we are, Doctor, you criticized Dr. Bierman today for having drawn a distinction between this being an equation as opposed to a model, but in your deposition, you pushed back on that very point and resisted the term "model" and said that was a bit too strong, correct?

A. Yeah, I think one can probably use "model" and "equation" in this case nearly interchangeably because, as I've explained, a model in the simplest form is a single equation.

Q. So were you just arguing with Dr. Bierman over semantics, "model" versus "equation"? Is that what it boils down to?

A. My recollection is it was the other way around, that Dr. Bierman was the one arguing regarding the semantics.

Q. Now, Doctor, this empirical equation that we've been calling your routing model doesn't explicitly model any physical process, does it?

A. No. And it wasn't necessary to explicitly model the processes.

Q. And this model runs off of, to some extent, these coefficients that we've been discussing; for example, the coefficients A, B and C. You agree with me, do you not, Doctor, that your coefficients A, B and C do not have any specific physical meaning, do they?
A. Well, certainly some of them would. And I guess there's maybe a little bit of a fine line here between whether they are physically based and you can measure these by going into the lab and performing an experiment or whether they're calculated the way I did. But there's still some physical interpretation of these.
Q. Let me ask it more directly, Doctor. You agree there's no physical meaning tied to these coefficients, A, B and C in your routing model?
A. I'm not sure that I would fully agree with that statement.
Q. Do you still have your deposition open, Doctor? Could you find page 207 of your deposition beginning on line 22. We're going to read carrying over to line 8 of the following page. I'll give you a moment. Have you found that yet?
A. What page and line numbers?
Q. Page 207, beginning on line 22. Are you there?

A. Line 22, yes.

Q. And I asked the question, Doctor, and you tell me if I get this wrong:

"Dr. Engel, with respect to the optimization of your phosphorus routing model, were there any limits on the degree to which these coefficients and the values associated with them, A, B and C, could be moved in one direction or the other by the computer?"

And your answer was:

"No, there would not have been, and one would -- again, because there's not a physical meaning tied to these, there would be no reason to constrain these. So, in fact, if, you know, these could vary from zero to some very large number, I suppose. And I guess if there was assigned a value of zero, that there would be meaning to that."

Did I read that correctly?

A. Yes.

Q. Doctor, in your own words, in your deposition, you've stated that there's not physical meaning tied to these coefficients. Do you disagree with that today?

A. Well, in the deposition also, there are at least two, three, maybe even more additional

locations where I did argue that they did have some physical meaning. So there are other places in here where, upon further reflection in talking through this, I did explain that they did have some physical meaning, some physical interpretation. So --

Q. Doctor, why would you say it both ways? Why would you say at one point they have physical meaning and at another point they don't? Do you not understand how these coefficients work?

A. I understand how the coefficients work certainly. So -- and I think I gave a specific example elsewhere in the deposition that talked about the value for the A coefficient would represent the expected phosphorus loads when there was no flow. And so that one certainly has some physical meaning. The B and the C, less so. So they're rate coefficients.

Q. Well, let's focus on A, because you said in your direct testimony one of the points that you were a little critical of Dr. Bierman's analysis on was the -- his A coefficient.

And I think your point -- you tell me if I've got it wrong -- is that today you ascribe some physical meaning to coefficient A and that that tells you what the phosphorus load should be at zero

flow; is that right?
A. Well, it wasn't just today. So in my deposition, I described that as well. And if one, you know, looks at the equation and thinks through this logically for a moment, so if there's no flow, the only term that remains in the equation is A, and so any value that A takes on, then, would be the expected load when there's no flow.
Q. And -- I'm sorry.
A. So I think that's consistent with what I described earlier today.
Q. And I think the observation that you were sharing -- you tell me if I've got it wrong -- is that given the description that you've just provided, you would expect the A coefficient to be zero because you would not expect in the real world any amount of phosphorus to be delivered to the lake in the absence of flow; is that right?
A. It would be near zero, if not zero.
Q. Well, is your A coefficient zero in any of your modeling runs in this case?
A. It's near is 0.1, so potentially there could be diffusion of phosphorus across some boundary without flow. So that's why, you know, saying that it has to absolutely be zero would probably be an

overstatement, but...
Q. Did you study diffusion of phosphorus in the absence of flow in arriving at .1 for your A coefficient?
A. No, the coefficient was constrained within that range.
Q. And you'll agree with me, Doctor, that your model, just like the modeling runs by Dr. Engel (sic), if we were to interpret coefficient A in the way you've just described it as having some physical meaning, delivers some amount of phosphorus to the lake even in the absence of flow, right?
A. I believe it delivers 0.1 units in those conditions.
Q. You and Mr. Page had a discussion about mechanistic models versus empirical models. Do you recall that?
A. Yes.
Q. I believe you cited Dr. Storm's prior work in this case as perhaps, you know, influencing your decision to not use a mechanistic model. Did I get that right?
A. Correct.
Q. And I think your point was a mechanistic model would introduce potentially too much error or

uncertainty?
A. Well, it would have the potential in some cases to do so.
Q. Now, you're not saying, are you, Doctor, that just because it is challenging to mechanistically model the actual physical processes that occur in a complex system like the Illinois River stream network, that you should simply disregard that step in the analysis?
A. Well, the question is presupposing that it's necessary to model those. And it depends on the question -- depends on the goals of the study as to whether it truly is necessary to model those processes.
Q. That was not one of the goals of your study, was it?
A. The goals of my study were to understand phosphorus delivered to the lake and to the gauging stations nearest the lake, and to be able to use that information to ultimately determine what happens under various scenarios and to determine potential allocations of that phosphorus to various sources.
Q. Doctor, are you aware that EPA intends to use a mechanistic model to model the Illinois River

Watershed as part of its TMDL?
MR. PAGE: Objection, Your Honor, assumes facts not in evidence.
MR. GEORGE: I asked whether he was aware.
THE COURT: Overruled.
THE WITNESS: I'm not sure that I've seen any indication whether they were or weren't.
Q. (By Mr. George) If they were headed down that path, would that be a mistake, in your view?
A. Based on my conversations with other scientists, based on my review of data and scientific reports for the Illinois River Watershed, I think that will present some real challenges.
Q. Let's look at these coefficients in a little detail and talk about how they are created. Doctor, the coefficients are calculated, their numeric values, prior to using the model for the forecast and the hindcast; is that right?
A. Yes.
Q. But when you first selected -- I think we established this earlier -- your particular routing equation, the coefficients did not have specific numerical values, right?
A. When I wrote the form of the model, the coefficients had, I guess, letters as placeholders,

and those specific numeric values were later determined, as we've discussed.

Q. They were determined as part of the calibration process, right?

A. Yes.

Q. And so the way this works, Doctor, is you started by taking the output from your GLEAMS model to represent runoff in the Illinois River Watershed for 1998 to 2006, right? That was one of the first steps in your calibration process with the routing model?

A. Right. So GLEAMS was run to obtain those outputs.

Q. Then you added to that the wastewater treatment plant loads for the same time period, right?

A. Correct.

Q. Then you put that combined sum -- and the routing model doesn't care the difference between the two -- into the daily P to river value in your routing model, correct?

MR. PAGE: Objection, Your Honor. I think that question is ambiguous. I don't know what he means, a routing model doesn't care the difference --

MR. GEORGE: If it's unclear, I'm happy to

-- I'll withdraw the question, Your Honor.

THE COURT: Very well.

Q. (By Mr. George) Let me ask it very directly. The P to river column in your routing model where these loads show up --

A. Right.

Q. -- is a single value combined for wastewater treatment plants and nonpoint source predictions from GLEAMS, right?

A. Yes, it combines those.

Q. The routing model does not try to disaggregate those in any way as it is routing them through the stream network, does it?

A. No, it would not.

Q. So from the perspective of a routing model, if a routing model can have perspective -- and I understand Mr. Page's concern -- the source of the phosphorus feeding into that routing model is immaterial, right?

A. Well, so -- no, but let me expand upon that because there would, I guess, be cases where that may not be true.

Q. Let's talk about this case. Is it true in this case?

A. Well, so I combined those in this particular

case. But there were physical constraints on the system so that I didn't arbitrarily increase values and put them in. So...

Q. So once you had these loads fed into your routing model, you then used this shuffled complex evolution algorithm written by Dr. Jeon, right?

A. No. The SCE, shuffled complex evolution, algorithm is an algorithm that is widely described in scientific journals and elsewhere. It's a widely used algorithm, so it was necessary only to code what's been described by others to create the calibration process.

In fact, that same shuffled complex evolution approach is used by others as they calibrate mechanistic models and identify coefficient values in those.

Q. Doctor, do you still have your deposition with you?

A. Yes.

Q. Could you turn to page 204. And beginning with the question on line 5, I want to direct your attention to the next five lines. Do you see, Doctor, that I asked this question in your deposition:

"Well, who wrote this code that you're

talking about from which the variable or the coefficient for B was determined?"

And your answer was:

"So the shuffled complex evolution code was written by Dr. Ji-Hong for this particular application."

Do you see that?

MR. PAGE: Your Honor, I object. That's not inconsistent with Dr. Engel's testimony.

THE COURT: It's not, particularly if you go on and he states the code is well established or the algorithm approach from shuffled complex evolution is a well-established technique, etcetera. I think it can all come in. Overruled.

Q. (By Mr. George) Dr. Engel, perhaps I misunderstood you, and if I did, I do want you to straighten me out.

Did Dr. Jeon write some code that was used in determining these coefficients for this particular application that involved the shuffled complex evolution?

A. Yes, he would have written code that implemented the shuffled complex evolution algorithm that was picked up from other places as described later in the deposition here. So, yes, it was

necessary to write equations that were pulled right from scientific papers for that piece of code.
Q. So, Doctor, then this SCE runs the equation, the routing model, if you will, over and over again until it determines what you refer to as the optimal values for the coefficients, right?
A. Yes, that would be the process.
Q. And as we discussed last time you were here, and I think you talked about this as well today, you served a report and two different errata in this case, right?
A. Yes.
Q. And you had to recalibrate your routing model for your errata, didn't you?
A. Correct.
Q. And when you did that, you got different coefficients, right?
A. Yes.
Q. And I believe you said -- and I wrote this down -- on direct that you had to recalibrate your model because the inputs changed when you added back in the HRUs that were accidentally left out, right?
A. Yes. So I had made a mistake in the GLEAMS model piece of this, so the GLEAMS inputs into my routing equation were incorrect. And so for that

reason, I did have to recalibrate.
Q. Just so we're clear, in the modeling realm that we've been discussing here, if the inputs to your routing model change, that requires a recalibration of the routing model, right?
A. No, that is too general of a statement and too general of a characterization of this. So --
Q. Let me stop you there.
MR. PAGE: Your Honor, the witness had not finished his answer.
Q. (By Mr. George) Go ahead.
A. So let me regain my train of thought here just a moment.
Q. You said that's not always the case?
A. That's not always the case. So in this instance, since the GLEAMS inputs had changed which were providing a boundary condition for this modeling, it was necessary to then recalibrate this. So one wouldn't arbitrarily create new inputs to the routing model and change the coefficients. If one did that, it would no longer represent this location. It would represent some imagined location.
Q. But for whatever reason, you found it necessary when the inputs from GLEAMS to your routing model

changed between your first report and your second report to recalibrate, correct?
A. Yes.
Q. Okay. When you did that, you got different coefficients for A, B and C, did you not?
A. Yes, there were some differences.
Q. Okay. And you also recalibrated the model separately for each of the three subwatersheds, didn't you?
A. Well, so there was -- yes, there would have been a recalibration for each of the three locations: Barren Fork, Caney Creek and Illinois River at Tahlequah. So that was the one group of recalibrations.
Q. Okay. And when you did that, you got different coefficients as compared to your first report for each of those three watersheds, right?
A. Not recalling if they were all different, but there were certainly some differences.
Q. Now, Doctor, during this calibration process that we've been discussing, the computer was not constrained as to what values to use for coefficients A, B and C, was it?
A. It was constrained within some range, as I recall.

Q. Well, do you still have your deposition with you? Can you turn to page 207, beginning at line 22, carrying over to page 208, line 13. Actually, let's focus in on beginning on line -- I'm sorry -- I guess we have to do the whole thing.

Do you recall being asked at your deposition the following series of questions:

"So is optimization another way of saying you're varying the data or the inputs into the model or model or in this case, the equation?"

And your answer:

"Probably a better -- maybe a better term would have been it's a calibration or identification of these values that are optimized to fit the equation between the observed data and the modeled data."

Then I asked a follow-up question:

"Dr. Engel, with respect to the optimization of your phosphorus routing model, were there any limits on the degree to which these coefficients and the values associated with them, A, B and C, could be moved in one direction or the other by the computer?"

And your answer:

"No, there would not have been, and one

would again -- because there's not physical meaning tied to these, there would be no reason to constrain these. So, in fact, you know, these could vary from zero to some very large number, I suppose, and I guess if they were assigned a value of zero, there would be some meaning to that. So a value of zero would indicate that the term in this equation didn't provide any further explanation in explaining the relationship between the phosphorus delivered to the three gauging stations and the wastewater treatment model inputs to those equations."

Did I read that correctly?

A. Yes.

Q. It's true, is it not, Doctor, that you told me in your deposition that there was no reason to constrain the movement of these coefficients in your calibration?

A. My recollection is that following this, there was probably a half-hour conversation on the limits of these coefficients, though, so I think we revisited this topic and corrected some of this statement. And, in fact, my recollection is that we looked at, you know, a series of files that did show potential constraints on these and talked about those, like I said, probably for 30-plus minutes on

the second day of the deposition.
Q. You don't disagree that what we just read was the testimony that you provided in your deposition?
A. I don't disagree that that's what it said here.
Q. I guess I have the same question, Doctor. Were you confused as to these coefficients and how they were adjusted in the calibration process when I first asked you about this in your deposition?
A. It appears that there was some confusion, based on this section, but there were broader discussions of these later within the deposition that corrected this.
Q. Just so we're clear. Where you are today is that there are some constraints on how far you can move those coefficients; is that right?
A. Well, the limits on these coefficients would be somewhat watershed and location specific. So there probably are some constraints, but, again, I think as I said here, they're probably pretty large. And based on the files that we looked at and the ranges that were looked at in subsequent testimony in the deposition, those ranges were pretty large that were used in allowing the model to search out optimal values for those.
Q. Doctor, the purpose of the calibration

exercise, as I understand it, was to identify the set of coefficients that would produce predicted P to lake loads that best fit the observed P to lake loads; is that right?
A. Yes.
Q. And fit here is, again, measured by regressing the predicted loads against your observed loads as we looked at earlier?
A. That was certainly one measure.
Q. Now, Doctor, you have criticized the -- what I call the sensitivity analysis -- I'm not asking you to embrace that term -- that Dr. Bierman offered on the basis that when he input his meta input phosphorus loads into your routing equation, he changed the coefficients, right? That's one of your criticisms?
A. Yes.
Q. But you understand, do you not, Doctor, that Dr. Bierman followed the exact same process that we just walked through with regard to your calibration?
A. Well, the process maybe wasn't exactly the same, nor were some of the constraints the same.
Q. Let's break it down. You understand, Dr. Engel, that Dr. Bierman took your routing equation spreadsheet, that's the vehicle he used for

his test, right?
A. Right.
Q. Okay. He removed your GLEAMS plus your wastewater treatment loads, the inputs, correct?
A. Right.
Q. He replaced that data with new inputs, correct?
A. Yes.
Q. A couple of different versions, whether it's reversed or it's an increased nonpoint source or increased wastewater treatment plant or the S&P 500, he made all of those replacements in terms of inputs, right?
A. Yes.
Q. For each set of inputs, he recalibrated your model, correct?
A. That was what he did, yes.
Q. And he found coefficients as a result of moving these values up and down like -- that result in predicted loads to the lake that are strongly correlated to the observed phosphorus loads to the lake, didn't he?
A. He did, but there are a couple of problems with that that I described earlier this morning.
Q. Let me pull up Tyson Demonstrative 381.
MR. GEORGE: May I approach, Your Honor?

THE COURT: You may, sir.

Q. (By Mr. George) Doctor, what we've put on the screen and what I've handed to you is a demonstrative exhibit that follows each of your and Dr. Bierman's calibrations through the process and shows the R^2 results and the Nash-Sutcliffe results.

And there are four pages. The first two pages relate to a comparison of your second errata phosphorus loads and R^2 with Dr. Bierman's sensitivity analysis, and then the last two pages focus on the S&P 500.

The reason I've broken them out, you recall, do you not, that Dr. Bierman only did his S&P 500 test on the Illinois River main stem, right?

A. Correct.

Q. So, Doctor, you understand this schematic in terms of what is shown. You see in the top panel the magnitude of the increases that Dr. Bierman applied. And you discussed this, I believe, in your direct to -- as compared to your second errata and some of his tests, you see the increased nonpoint source and the increased wastewater treatment plant?

A. Yes, I see those.

Q. Those are substantial increases over the loads that you used that are shown in the second errata, do you see that?
A. Yes.
Q. And then he fed that information through the routing model. And the way your routing model works, when you feed in new loads and it runs, it generates R^2 and Nash-Sutcliffes, right?
A. Correct.
Q. And he calibrated your routing model as part of these tests as well, correct?
A. Well, he -- I wouldn't call what he did a calibration. You know, the inputs didn't reflect any sense of reality and nor did the observed loads reflect what would occur under those conditions, so I would disagree with your description of this.
Q. Let's look at the results in terms of R^2 values. You see in the bottom that there's a chart there that shows the R^2 values that you report from your second errata for each of these subwatersheds. What's the range of those R^2 values?
A. So it looks like from .62 to .97 maybe.
Q. Then, Doctor, the next three rows show the R^2 values computed by the routing model for the three different scenarios with increased or different

loads by Dr. Engel, do you see those?

MR. PAGE: Your Honor --

MR. GEORGE: I'm sorry, by Dr. Bierman.

MR. PAGE: I think that's testimony that's not in evidence. There's been no evidence of these R^2 with this procedure by Dr. Bierman.

MR. GEORGE: I think Dr. Bierman, who Dr. Engel is here rebutting, testified at length about the R^2 values and his tasks compared to Dr. Engel's.

THE COURT: Overruled.

Q. (By Mr. George) Do you see those values, Doctor?

A. We're talking about the increased NPS line of this table?

Q. Yes. We can take all three of them, if you want to, for efficiency, the increased nonpoint source load, the increased wastewater treatment plant loads, then reversing your daily phosphorus loads.

A. Right.

Q. What's the range of R^2 values that Dr. Bierman got when he recalibrated your model and ran his tests?

MR. PAGE: Objection, Your Honor. That's

contrary to the witness's statement. The witness has disagreed with counsel that Dr. Bierman recalibrated his model.

MR. GEORGE: Your Honor, we could quarrel over this all day long, I suspect, in terms of semantics. If there's another phrase that the doctor would like for me to use, I would be happy to.

THE COURT: Overruled. Go ahead.

Q. (By Mr. George) What are the range of values, Doctor?

A. Well, the range of values are like .72 to .97.

Q. Doctor, those are as good, if not better, than the R^2 that you report using what you claim are more realistic phosphorus loads, right?

A. Yes.

Q. If you'll turn to the second page, Doctor, it's the same format. The only difference here is we've shown the Nash-Sutcliffe values as opposed to the R^2 values in the bottom panel. Do you see that?

A. Okay.

Q. For the benefit of the record, in your second errata, you agree with me the Nash-Sutcliffe values that you report range from .55 for Caney Creek to .96 for the Illinois River?

A. Yes.
Q. And then we have a comparison with Dr. Bierman's test with increased loads. And do you agree that they range from a low of .76 to a high of .96?
A. I'm not sure I would characterize it as a test, but I mean, the numerical values reported in the table are in that range.
Q. Those are as good, if not better, than the Nash-Sutcliffe values that you obtained using what you claim to be more realistic phosphorus loads, right?
A. I'm not sure I would characterize them as good or better. So there's, again, broader context that these were done in many cases with unrealistic values, and so making that interpretation would be inappropriate.
Q. Are the Nash-Sutcliffes higher in his analysis as compared to yours?
A. Looks like in some instances, the Nash-Sutcliffes in this table are higher.
Q. Doctor, if you'll turn to the third page, the format is the same, only now we've shown the S&P values that were replaced in Dr. Bierman's analysis. And you see at the bottom that we again

have a comparison of R^2 values.
A. Yes.
Q. As compared to what you obtained in your second errata using what you claim to be more realistic phosphorus loads, Dr. Bierman obtained the same R^2 in his evaluation, did he not?
A. The reported values are the same, yes.
Q. They're both .97, aren't they?
A. Yes.
Q. That suggests a strong correlation between the S&P values that he plugged in and the phosphorus loads at Lake Tenkiller, doesn't it?
A. Well, there were other problems with the S&P analysis, as I talked about this morning, and so when the models were uncoupled, you know, the S&P was providing nonpoint source inputs on days that it didn't rain, which logic tells one that wasn't happening.
So there has to be context with some of these, so when you rip these apart like this, you lose context. And just looking at R^2 may not mean a lot in this case.
Q. So I want to make sure I understand. R^2 don't mean a lot in this case; is that your testimony?
MR. PAGE: Objection, Your Honor, that's

not his testimony.

THE COURT: Sustained.

MR. GEORGE: I'm sorry if I misunderstood.

Q. (By Mr. George) Dr. Engel, let's look at the last page of this demonstrative just to close the loop on this. We again have the loads for the S&P 500 in place of the phosphorus loads that you used, and then at the bottom a comparison of the Nash-Sutcliffe this time as opposed to R^2. Do you see that?

A. Yes.

Q. Once again, is it true that Dr. Bierman obtained the same Nash-Sutcliffe .96 using the S&P 500 Index values as compared to your phosphorus loads in your second errata?

A. The reported numerical values were the same. And, again, this same contextual issue would apply in that by decoupling the models, we've now created an unrealistic set of inputs that don't match what's happening.

Q. Doctor, given that you can calibrate this model for five different sets of inputs and have all of those generate results that correlate equally well to the same observed loads, there's no way of knowing which calibration is correct, is there?

A. No, I would disagree with that.
Q. If you can calibrate the formula to correlate with your observed loads regardless of how extreme the input, we can be confident that the one thing this equation does not do is confirm that your inputs are correct, right?
A. I would disagree with that.
Q. Let's talk about coefficients for a moment, Doctor. You criticized Dr. Bierman for not holding your coefficients constant when he ran his analysis; is that right?
A. Yes, that was part of the criticism, yes.
Q. I think, if I understand your testimony, you think a better test would have been to change the inputs and leave the coefficients alone, right?
A. Well, it depends on what one is trying to test, I suppose.
Q. Okay. But that was one of your criticisms is that Dr. Bierman should have changed -- if I misunderstand, tell me -- if he wanted to do a test, he should have changed the inputs but left the coefficients alone and see how the model performs?
A. So that would have been a test of increased phosphorus loads and how they would be routed through the streams systems.

Q. In fact, in preparation for your testimony today, you did exactly that test, did you not?
A. Yes.
Q. You took Dr. Bierman's increased phosphorus inputs, you held the coefficients constant, and then you ran your model, right?
A. Correct.
Q. And you're aware that Mr. Page produced those results, the spreadsheets from those tests to the defense counsel this past week in preparation for your testimony today? Did you know that?
A. Right.
Q. Did you review the R^2 values that were generated by the tests that you performed, taking Dr. Bierman's increased phosphorus inputs, holding your coefficients constant and rerunning the model?
A. I don't know that I looked at all of those and did a complete analysis of those.
Q. Did you look at them at all?
A. I looked at them in the spreadsheets very briefly, but didn't step back and do much of an analysis.
Q. They're kind of hard to get away from because they pop up on the spreadsheet, don't they?
A. Right.

Q. You did at least look at least preliminarily at some of those R^2, right?
A. Right.
Q. Isn't it true, sir, that for all of Dr. Bierman's made-up scenarios, the predicted loads to the lake using the model that you developed with your coefficients still strongly correlates to the observed loads to the lake?
A. I don't recall that, but...
Q. Let's take a look. Pull up the native version of Defendants' Joint Exhibit 8147. I think it's on the screen, Doctor, and you'll see the file name at the top, if we can -- I don't know if it's visible. Is it visible this time, the file name at the top is Bierman0017368-P_model_10_15_SP500_Engel_COEFF.xlsx. I need to correct the -- the reference is actually Exhibit 8140.
Did I read that file name correctly, Doctor?
A. Yes.
Q. You recognize that file name as being associated with the test that you ran subsequent to your prior testimony, taking Dr. Bierman's inputs, using your coefficients and rerunning the model, in this case the S&P 500?

A. Yes.
Q. And do you see the R^2 that are generated from this test using the coefficients, as you say they should be, unchanged?
A. Yes.
Q. And for the record, what are the R^2 values?
A. Looks like it's 0.956 maybe. There seems to be a data point maybe in the way there.
Q. 0.9565; is that correct?
A. 0.95 something, and the something seems to be a 6 or a 5. Seems to be tough to read on my monitor.
Q. And if we go to the next one, the R^2 is 0.9844?
A. Well, this one is unchanged. The S&P was only input on the Illinois River, so I believe unless the spreadsheet has been rearranged...
Q. Let me see if I can clarify. You see there are three and only three charts on this particular spreadsheet. Do you recognize that those charts relate to the three different time periods that we discussed earlier, '98 to 2006, 2003 to 2006, and '98 to 2002?
A. Correct.
Q. All three for the Illinois River Watershed?
A. Right.
Q. So the second R^2 value in this model run by you

is .9844; is that right?
A. That's tough to read. Sorry. Looks like it's 0.984 is what I'm seeing.
Q. Then the last one. What's the R^2 value?
A. Looks like 0.949.
Q. Now, Doctor, let's compare those R^2 values to the R^2 values generated by your own October model run that underlies your most recent report in this case. Pull up Defendants' Joint Exhibit 8150. See that on the screen, sir?
A. Yes.
MR. GEORGE: May I approach, Your Honor?
THE COURT: You may, sir.
Q. (By Mr. George) Doctor, you'll see on this exhibit that we have taken the R^2 in the middle column which are from your report or your errata and compared those to the R^2 that you just read into the record. Do you see that?
A. Yes.
Q. And once again, the R^2 obtained from your reevaluation of Dr. Bierman's S&P 500, using your coefficients, are as good as or if not better than the R^2 that you rely upon in your original report -- I'm sorry, your second errata.
A. So, yes, the R^2 are of similar magnitude, but I

would add that there's more to the story than that probably.

Q. Well, let's compare the R^2 values from all of the spreadsheets that you produced where you held your coefficients the same and used Dr. Bierman's unrealistic loads.

MR. GEORGE: May I approach, Your Honor?

THE COURT: You may.

Q. (By Mr. George) Doctor, I've handed you and we've placed on the screen what's Defendants' 8151, which is a chart that shows the R^2 values from your files produced to us where you reevaluated Dr. Bierman's work using your coefficients for each of his four tests, including the S&P that we just discussed, with your original routing model results from your October errata. Do you see that? Do you understand this chart?

A. Yes.

Q. And this chart shows, does it not, Doctor, that even when you hold your coefficients constant and you run the inputs by Dr. Bierman, which you've testified are unrealistic in terms of phosphorus inputs into this system, the model in all three watersheds or subwatersheds produces R^2 values that are within the range or better than the R^2 values

that you rely upon for your testimony in this case?
A. Yes. But, again, the R^2 are not the entire story, so one has to look at the magnitudes of outputs. It would be interesting to look at the Nash-Sutcliffe values on some of these as well.
Q. Have you done that? Have you looked at the Nash-Sutcliffes?
A. I don't recall that I looked at those explicitly in this case.
Q. Let's look at this topic in a different way, Doctor. You plotted the results of your revised analysis on some demonstrative charts. And in particular, I'm referring to State's Demonstrative 416 and 417.
A. Yes.
MR. GEORGE: I believe Your Honor already has these, but if you need another copy, Your Honor, let me know.
THE COURT: No, sir.
Q. (By Mr. George) Do you have these, Doctor?
A. If you've got them handy, it might be quicker than me looking through the stack.
MR. GEORGE: May I approach, Your Honor?
THE COURT: Yes.
Q. (By Mr. George) Doctor, you created these two

demonstratives, State's Demonstrative 416 and 417, correct?
A. Correct.
Q. And these are the product of the tests of the spreadsheets that we just explored, correct?
A. Yes.
Q. And in essence, these show the differences in terms of combined phosphorus output using your coefficients as opposed to the ones used by Dr. Bierman for two of the tests that we've been discussing, the first being with the loads reversed and the second being the S&P; is that right?
A. Yes.
Q. And as a matter of format, the red bars are the predicted loads to lake calculated by your model, and the blue bars are the predicted loads to lake calculating replacing your loads with Dr. Bierman's made-up loads but using your coefficients, right?
A. Yes.
Q. And your point, as I understand it, is that different inputs generate different output loads; is that the point?
A. Yes.
Q. Okay. You do understand that Dr. Bierman never said anything to the contrary on that point? Did

you review his testimony?
A. Yes, I did.
Q. Okay. Dr. Bierman never testified that the model always produces the same numerical output, did he, in terms of loads to lake?
A. I don't know. I'm not sure.
Q. You're not sure whether that was his testimony?
A. I don't recall that -- if he did or didn't make that statement explicitly.
Q. Do you recall, in reviewing Dr. Bierman's testimony, seeing him discuss the results of the model in terms of R^2? You did see that in his testimony, didn't you?
A. Yes.
Q. Now, on the two demonstratives that I put in front of you, Doctor, you see that both sets of input data generate results showing similar patterns? Did you notice that?
A. Yes.
Q. So even though the amount of the load quantified might change, the patterns over time of those loads look very similar, don't they?
A. Yes, and I would expect they should.
Q. And, Doctor, that's true even when the input data is something as far removed from actual

phosphorus loads as the S&P 500. The pattern in terms of what your model produces as phosphorus loads to the lake is similar, right?
A. Well, when you say, "as far removed as the S&P 500," it turns out that if you look at the S&P 500 inputs across these nine years and you look at the distribution of the S&P 500 values, that, in fact, they are similar to the combined GLEAMS and wastewater treatment, so based on that, that's not a surprise.
Q. Well, Doctor, your routing model calculates or predicts phosphorus loads on a daily basis, right?
A. Yes.
Q. The S&P 500 fluctuates on a daily basis, right?
A. Yes.
Q. And the actual phosphorus loads in the watershed fluctuate greatly on a daily basis, do they not?
A. Yes, they would.
Q. Do you think it is just coincidence that in your analysis that the fluctuations in phosphorus loads in the system correspond in terms of pattern to the fluctuations in S&P 500 Index values?
A. I'm not sure what you mean by the fluctuations in the system.

Q. Well, in terms of how phosphorus actually moves when we have rain events, when we don't.
A. Well, the routing model is -- you know, is simply looking for loads. And if you give it phosphorus loads of similar magnitude with a similar distribution, it's not surprising it's going to produce similar results.
Q. Doctor, don't the two demonstratives that we've been looking at here, 416 and 417, show us that some factor other than the phosphorus input is driving this model?
A. No, I wouldn't reach that conclusion from these demonstratives.
Q. Well, you would reach that conclusion otherwise, would you not? Something other than phosphorus inputs is driving this routing model and its flow, isn't it?
A. Well, certainly flow drives loads that are delivered to the gauging stations. So you can't escape that. I mean...
Q. Flow drives the output of this model regardless of the phosphorus input loads that you feed into it, doesn't it?
A. I would disagree with that.
Q. Let's look again at your October 2008 routing

model that we've had on the screen a time or two. Doctor, I want to cover one more thing on these coefficients and then move on to something else.

Let's look at the coefficients that you calculated for the Illinois River subwatershed. And your coefficient A is in cell H3. And do you see it is 0.1?

A. Yes.

MR. GEORGE: Mr. Todd, can you change that to 90.

Q. (By Mr. George) Doctor, when we change this coefficient and we hit enter, the model reruns, doesn't it?

A. It probably should, yes.

Q. What's the R^2 value now? Do you see that first chart?

A. Looks like 0.975.

Q. Did you happen to see what it was before?

MR. GEORGE: Mr. Todd, can we go back and let him see a comparison of the change.

Q. (By Mr. George) Did it change much, Doctor?

A. No, it didn't change much.

Q. Let's go over to coefficient B, which is cell H4. There the coefficient is 0.000000347; do you see that?

A. Okay.

MR. GEORGE: And, Mr. Todd, let's double that coefficient. Take it up to the same number of zeros, just 647 instead of 347.

Q. (By Mr. George) That would be a substantial change in that coefficient, would it not, Dr. Engel?

A. It's a change in the coefficient.

Q. Did the R^2 values change much when we changed that coefficient?

A. No.

Q. Now let's go over to coefficient C, which is cell H5. There the coefficient for C is a decimal, nine zeros and 105; do you see that?

A. Yes.

Q. And let's change that coefficient substantially as well. Let's double it to the same number of zeros, only 205. See that?

A. Yes.

Q. Okay. Did the R^2 values change significantly?

A. No.

Q. So, Doctor, you'd agree that substantial variations in the coefficients do not necessarily change the correlation results, do they?

A. Well, they don't change the R^2; they change the

Nash-Sutcliffe correlation coefficients and they make other changes as well. So maybe not just -- one would need to look broader than just the R^2.

Q. Have you evaluated that as part of your work in this case, how these coefficients impact either R^2 or Nash-Sutcliffes when you change them substantially in your model?

A. Yes. During some early use of the routing model, I would have examined some of those things.

Q. And did that examination confirm for you that you can change these coefficients significantly without substantially affecting the statistical measures that we've been discussing that are useful in evaluating the reliability of the model, R^2 or Nash-Sutcliffes?

A. They tend to have more influence on Nash-Sutcliffe values. So the influence there is certainly much greater than R^2.

Q. How much can we change them without having an undesirable impact on the Nash-Sutcliffe values? What's the range, Doctor?

A. I guess I didn't perform that specific evaluation that you're asking about.

Q. You commented on Dr. Bierman's testimony that USGS flow appears on both sides of your regression

analysis. Do you recall being asked that by Mr. Page?
A. Yes.
Q. Let's look at a chart to illustrate the point.
MR. GEORGE: Can you pull up Defendants' Joint Exhibit 8153.
May I approach, Your Honor?
THE COURT: You may.
Q. (By Mr. George) Doctor, you'll see what I've done here is we've taken one of your validation calibration panels from your spreadsheet, which is the P model_10-15, and we simply reproduced it on here and then put the formulas that are applicable on the left-hand side and the bottom. Do you see that?
A. Yes.
Q. Okay. And for the record, the Y axis relates to the total phosphorus load; is that right?
A. Yes, that's what it seems to be.
Q. That's model output or predictions; is that right?
A. It looks like, at least based on the label here, that this seems to be predicted phosphorus loads based on a routing equation, routing model.
Q. This comes -- you're not unfamiliar with this

chart? You've seen it before, haven't you?
A. I'm not recognizing it offhand, but...
Q. The X axis, you'll see that it references observed total phosphorus loads?
A. Okay.
Q. And that's how you compute these R^2 values, right? You compare predicted loads with observed loads?
A. Yes.
Q. Do you see the formula that appear -- let's start with the one along the Y axis. Can you read that formula into the record, please.
A. The one on the Y axis?
Q. Yes, sir.
A. That says P load equals A plus B times Q times P accumulation plus C times Q^2 times P accumulation.
Q. You recognize that formula, don't you, Doctor?
A. Yes.
Q. That's your routing equation?
A. That's my routing model, yes.
Q. And flow, in particular USGS estimated flow, shows up twice. And then in one instance, it's actually squared in that formula, right?
A. Yes.
Q. Now, let's look at the formula that is used to produce the -- what we've been calling observed

loads or USGS loads along the X axis. Do you see that at the bottom?

A. Yes.

Q. I won't ask you to read it because it's long, but do you see that the formula that's used by USGS to calculate observed total phosphorus loads includes Q, which is flow, and Q^2 , which is flow?

A. Yes.

MR. PAGE: I hate to interrupt, but can we take a short break?

THE COURT: We'll do so. We'll be in recess for 15 minutes.

(Whereupon a recess was had.)

Q. (By Mr. George) Dr. Engel, we were discussing Exhibit 8153 which is still on the screen that involves the regression analysis that computes these R^2 values comparing predicted total phosphorus loads from your routing model with the observed loads computed using USGS Model 8; do you recall that?

A. Yes.

Q. I think we established that on both the X axis and the Y axis, you have data that is generated from equations that are dependent upon flow and $flow^2$, correct?

A. Yes.

Q. And you would agree with me, sir, that if flow dominates both of these equations, then we would expect to see the outputs of these two equations consistently correlate with each other, wouldn't we?
A. They may be correlated, but, again, there's more to the understanding than just correlation.
Q. In fact, sir, isn't that exactly what has happened here, is that each of your regression analyses is really just regressing observed USGS flow onto itself?
A. No.
Q. You don't believe that's why we see consistently good R^2 values regardless of the phosphorus inputs and regardless of the coefficients?
A. No.
Q. Doctor, you mentioned Nash-Sutcliffes and perhaps the coefficient changing having a more substantial impact on them, so I want to go back, if we can, for just a moment.
MR. GEORGE: Mr. Todd, can you pull back up the spreadsheet that we were looking at on changing coefficients. I believe it is 8154.
Q. (By Mr. George) Doctor, we're going to go through the same exercise here, and we're going to

focus this time on the Nash-Sutcliffes and we're going to change coefficient A for the Illinois River from .1 to 90, which is the same change we made before.

MR. GEORGE: Mr. Todd, can you show both the resulting Nash-Sutcliffe coefficients and the coefficients at the same time? Can you split the screen? Have you already done that?

MR. TODD: Yes.

MR. GEORGE: It would be nice if you would tell me that. Technology, Your Honor.

Mr. Todd, can you change .1 to 90, if you haven't already done that. Let's look at the Nash-Sutcliffes.

Q. (By Mr. George) Doctor, did you see that change? When the model reran with the 90 coefficient, was there a substantial impact on the Nash-Sutcliffe values for the Tahlequah station?

A. It looked like there was some change.

Q. We can do it again. What's the value right now?

A. Looks like .976499.

Q. Let's run it again with the change.

MR. TODD: It's now put back.

Q. (By Mr. George) What's the original value?

You just gave us the value with 90 as the coefficient.
A. Looks like .965559.
Q. So when we substituted 90 for coefficient A in the place of .1, the Nash-Sutcliffe actually got better, didn't it?
A. Looked like it changed slightly.
Q. Well, but it changed upwardly, correct? The number is higher?
A. Yes, it did go up.
Q. Both of those Nash-Sutcliffe coefficients -- or statistics are strong, are they not?
A. Yes, they would be.
Q. You also criticized Dr. Bierman's runs, the tests that he ran, because they resulted at least in one instance in a P accumulation in the rivers that you deem to be unrealistic. Do you recall that testimony?
A. Yes.
Q. If we could pull up State Demonstrative 396. This demonstrative relates to that testimony, does it not, Doctor?
A. Yes, it does.
Q. I believe you testified that because of the adding of phosphorus and the increase of phosphorus

in this column that is entitled P accumulation that phosphorus was disappearing. Do you recall that?
A. I suppose disappearing with quotes, and it was not reaching the gauging stations, so it had to go someplace.
Q. Terminology is important here, so I want to try to be precise. Dr. Bierman's recalibrated model that we're discussing here in this demonstrative does not remove phosphorus from the working of the model, does it?
A. No, it would not.
Q. So all of the phosphorus is accounted for. Your criticism is just that an unrealistically high amount of it accumulates in this column entitled P accumulation, right?
A. Yes.
Q. Doctor, you never used any real world data to set your initial P accumulation value for your routing model, did you?
A. I guess there would not have been real world data to set the initial value. But as I understand the Illinois River Watershed system, there's a fairly frequent flushing of phosphorus from these stream systems, so one would expect fairly complete flushing.

Q. Doctor, you had to make a decision on the front end as to how much phosphorus to start with in terms of an initial P accumulation in the model, correct?
A. Yes.
Q. And I think in all of your modeling work, you started with the same value, which was 500,000 kilograms; is that right?
A. I believe it varied by subwatershed.
Q. But whatever those values were, and I appreciate they may have varied from one watershed to the next, they were not based on someone going out and taking a measurement as to how much phosphorus is actually in those systems, right?
A. Correct.
Q. And you never used any real world data to compare the accumulated phosphorus values at the end of your model runs, correct?
A. There would not have been observed phosphorus accumulation data to compare it to.
Q. The purpose of this accumulated phosphorus was simply to allow for deposits and credits, if you will, deposits into the bank and credits out of the bank based upon what the model equation requires in terms of phosphorus loads at the lake, right?
A. Yes.

Q. This particular column was not intended to have any real physical meaning or basis in reality, was it?

MR. PAGE: Object to the form, Your Honor, that's contrary to the witness's testimony.

THE COURT: Rephrase, please.

Q. (By Mr. George) This initial P accumulation -- I'm sorry. This P accumulation column was not intended to have any physical meaning or basis in reality?

A. Certainly as you just described, it's a mass balance accounting mechanism, so certainly that does have some physical meaning, and one would expect it to be within certain ranges. And certainly something on the order of 589 million is well beyond a value that I would expect.

Q. Did you constrain this value in your modeling so that it could not exceed what you believe to be a realistic value?

A. Well, the value was constrained during calibration, and I'm not recalling what that constraint might have been. But then once the model is running, as you described this, this is simply a checking account. So you've got inputs, you've got outputs from it. So it's going to fluctuate based

on those inputs and outputs.
Q. Doctor, if I understand correctly, your model was not set up so that at some point in time when phosphorus accumulation in this column built up to a certain level, the model would shut down or give you a red flag that that's not realistic, right?
A. Well, I guess the red flag would have been of me, the modeler, looking at this set of results and seeing that, you know, this is an unrealistic value.
Q. What would you have compared it to to determine it was a realistic value?
A. I expect that this would have been within an order of magnitude of the starting value for the phosphorus accumulation, so something in that range would have been reasonable.
Q. Why would you have expected that?
A. Again, based on this concept that the streams are flushing during fairly large flows that happen every few years, maybe more frequently during some periods, that there's a pretty complete flushing of phosphorus from these stream systems.
Q. Let's approach this issue of accumulated P from a different angle, if we can. Doctor, you're familiar with the law of conservation of mass?
A. Yes.

Q. You understand that under that law, matter can be neither created nor destroyed?
A. Right.
Q. That that's sort of mass balance at its finest, right?
A. Right.
Q. And so you agree that in the real world of the Illinois River Watershed, phosphorus can't just appear or disappear, can it?
A. Right.
Q. It has to come from somewhere and go somewhere, correct?
A. Yes.
Q. Do you recall telling me at your deposition that your routing model does not create or lose phosphorus but, rather, simply distributes it?
A. Yes.
Q. And you would agree that it would be unrealistic for a routing model to simply create or destroy phosphorus, correct?
A. Right.
Q. Let's turn back to your October 2008 routing model spreadsheet. I want to look at one last series of columns here. Can we start with cell F5. And I think we agreed earlier that this shows the

routing equation for the Illinois River subwatershed that calculates the P to lake, right? See it up there in the formula?
A. Yes.
Q. And for the record, the formula is -- that shows up on the spreadsheet is dollar sign H dollar sign 3 plus dollar sign H dollar sign 4 times C5 times E5 plus dollar sign H dollar sign 5 times ($C5^2$) times E5. Did I read that correctly?
A. Yes.
Q. Now let's go over to column N in the Barren Fork subwatershed. Column N also calculates P to lake, correct?
A. Yes.
Q. If you look at the formula for cell N5, the equation is stated differently from what we just read, isn't it?
A. Well, I guess the first part of the equation is the same. But then there's a constraint so that you can't have a negative P accumulation so that you can't destroy phosphorus or lose phosphorus.
Q. Since we're creating a written record here, let me ask if I've got this right. In Barren Fork, the routing equation is -- begins with the word "if," then it's got the same routing model equation,

right?
A. It's different cells, but it's the same formula.
Q. Same formula? If, the same formula, then it's got greater than M5. What's that?
A. Looks like that is the amount of phosphorus accumulated on that particular date.
Q. And then in Excel language, there's a comma and it says, M5. Do you see that?
A. Yes.
Q. What does that mean, if the routing formula is greater than M5, then M5?
A. Looks like on those dates, we would have a complete flushing of phosphorus. So the amount of phosphorus delivered could only be the amount that had been accumulated within the, in this case, Barren Fork.
Q. Then there's some additional language that we haven't seen before that appears at the end of this formula. Do you see that?
A. Yes.
Q. And for the record, it's dollar sign P dollar sign 3 plus dollar sign P dollar sign 4 times K5 times M5 plus dollar sign P dollar sign 5 times ($K5^2$) times M5. Did I read that right?

A. Again, that's just the same as the first part of this "if" statement, so that's the routing model piece.

MR. GEORGE: Can we pull up Tyson Demonstrative 385. May I approach, Your Honor?

THE COURT: You may.

Q. (By Mr. George) Doctor, on Tyson Demonstrative 385, I had to have someone who understands Excel try to break this language down for me to make sure that I understand the formula. And I want to know if I've got this right.

If we were to speak English as opposed to Excel, the formula that we just read translates to if phosphorus to lake is greater than accumulated phosphorus, then set phosphorus to lake to accumulated P; otherwise, set P to lake per the normal routing equation, right?

A. Yes.

Q. Now, if we go over to cell V5 -- let me back up. Doctor, what this tells us is, if the routing model generates phosphorus to lake value that's greater than the accumulated phosphorus value, then the model should set the phosphorus to lake equal to the accumulated phosphorus value, right?

A. On that day, yes.

Q. Okay. Let's go over to cell V5 for a moment. And we're in Caney Creek now, right?
A. Okay.
Q. And you see the same expanded equation that is shown in that column as well, or that cell?
A. Okay.
Q. Now, Doctor, this equation that's shown on Tyson Defendant Demonstrative 385, that's not the equation you disclosed in your expert report, is it?
A. It looks like the equation is the same. It looks like it was necessary to impose a further constraint on days in which the accumulation wasn't large enough to solve this equation.
Q. And so to put it in simple terms, the equation actually reduces the phosphorus to the lake that your unmodified equation would calculate on those days, right?
A. Yes, that would be accurate.
Q. And so phosphorus is disappearing on those days, right?
A. No, it wouldn't be disappearing. So this would be a constraint that doesn't allow phosphorus to be lost or disappear.
Q. Well, it takes the product of the routing model

that predicts the phosphorus to the lake on a particular day and it reduces it to what is available in the accumulated P, right?
A. Right.
Q. If your predicted phosphorus load was correct, phosphorus is disappearing as a result of this patch, is it not?
A. I wouldn't describe it that way. It's just a constraint so that you don't exceed the balance of phosphorus available for transport that day.
Q. Doctor, it's true, is it not, that you had to come up with this constraint or patch -- I won't quarrel with you on terminology -- because when you ran your regular routing equation in these subwatersheds, the accumulated P and the P to lake actually went negative, didn't it?
A. I'm not sure -- I'm not sure that that was the case, so this was to prevent that from occurring. I don't recall if it actually would or did occur with the routing model coefficients that were provided.
Q. Were you not worried about this occurring in the main stem of the Illinois River, which is the other subwatershed?
A. My recollection was that in reviewing those data that the phosphorus accumulations did not dip

for the range of conditions to make it go negative.
Q. Do you recall it going negative in Caney Creek and Barren Fork?
A. I don't recall whether it did or didn't.
Q. Well, have you run this model without your patch for those two subwatersheds?
A. I think maybe it was initially run without that constraint.
Q. Well, Doctor, let's delete the patch from the spreadsheet. It's pretty easy to delete, isn't it, and run it and see if it goes negative?
MR. GEORGE: Looking at cell V5, Mr. Todd, can you take the patch out and run the routing equation without it?
Q. (By Mr. George) Doctor, let's go to cell V9 and see what it reports for the P to lake when we take this patch out. Do you see it?
A. Yes.
Q. Your routing equation without this fix actually shows a negative delivery of phosphorus to the lake of 478.9, correct?
A. That's the value reported in that cell, yes.
Q. Then if we go to cell U9, let's look at the accumulated phosphorus. How much phosphorus is accumulated in cell U9? It's a negative number,

isn't it?
A. Looks like it's a negative number, yes.
Q. Negative 1061.6?
A. Yes.
Q. Let's scroll down a couple of years and look at V908 through V912, those cells. They now report negative P in the river as well, don't they?
A. Yes.
Q. And cells U908 through U912 report negative accumulated P values, correct?
A. Yes.
Q. And cell V1156 --
MR. GEORGE: Would you pull that up, Mr. Todd.
Q. (By Mr. George) -- now reports a negative 600.1, correct?
A. Correct.
Q. Finally, cell U1156. It shows a negative amount of accumulated phosphorus of 1200.4, correct?
A. That's the cell that's highlighted, yes.
Q. Doctor, in the real world, you can't have negative accumulated phosphorus in the river, can you?
A. Correct, and thus the constraint to prevent that.

Q. In the real world, you can't have negative phosphorus to the lake, can you?
A. Correct. Again, thus the constraint to fix that.
Q. That's why you modified your equation, is when you ran your routing model, you actually produced negative values to the lake and to the river and in the accumulated P column, right?
A. Yes. As we see here, it was necessary to impose a constraint so the mass balances were enforced.
Q. That constraint was to make phosphorus that was predicted by the model, your routing equation, disappear, right?
A. No.
Q. You didn't disclose any of this in terms of the patch in your report, did you?
A. I don't recall if I did or didn't.
Q. Isn't it true, Doctor, that to avoid having negative accumulated P and negative P to the lake that you decided to break a fundamental law of physics, and you made mass disappear in your model?
A. No.
Q. Doctor, doesn't this suggest to you that your routing model doesn't accurately reflect real world

processes in the watershed?
A. No. In fact, I think this shows that there is this periodic flushing, as I've discussed.
Q. Doctor, I want to switch gears for a moment and talk about this issue of the omission of half of the watershed in your first report as compared to your errata. You know what I'm talking about generally?
A. Yes.
Q. And in your direct testimony today, you stated that 20 -- let me back up. You stated that the data for these 23 HRUs that were left out, my term, was in the model, right?
A. Well, the data was in the files that were accessible to the model, yes.
Q. That data was omitted from the calibration run; is that right?
A. Yes.
Q. I just want to make sure I understand and the record is clear on this. Dr. Bierman was right, was he not, when he said that in your calibration period of '98 to 2006 for your first report, you ran the model on only 27 of the 50 HRUs?
A. Now --
Q. That's right, isn't it?
A. No, that's inaccurate.

Q. How is that inaccurate?
A. So the model was run on all the HRUs. The calibration didn't access and adjust a group of HRUs beyond 27, so there would have been, I guess, 23 of those that did not have the benefit of calibration.
Q. But now the calibration that we're referring to is a model run, isn't it? You run your model in order to calibrate it?
A. Yes. The model would have been run as part of that calibration process.
Q. When you ran your model in order to calibrate it for your first expert report, the model did not process the data in 27 -- I'm sorry, in 23 of the 50 HRUs, right?
A. Only during the portion of what I described as the calibration piece of the nonpoint source calibration, but the model did consider the remainder of the HRUs, it just didn't benefit from calibrating.
Q. Let's talk about the national land cover data for a moment. You took issue, I think, with Dr. Bierman's testimony that the land use data that was used in your modeling work contained instances when areas of land were misclassified; is that right?

A. Yes.
Q. And if I listened carefully enough to your testimony, and hopefully I did, you don't deny that the national land cover data misclassifies land in the watershed, do you?
A. It would certainly have the potential to have some of it misclassified.
Q. Your point, as I understand it, is that to the extent there are mistakes in that dataset, those are mistakes made not by Dr. Engel but by USGS.
A. That would be correct.
Q. You did not investigate whether the national land cover data accurately classified urban as urban and pasture as pasture, did you, as part of your work in this case?
A. I did not perform that specific analysis.
Q. And so your beef with -- legal term, sorry -- beef with Dr. Bierman, as I understand it, is that he had the audacity to check the data; is that what this boils down to?
A. No.
Q. You're not critical of Dr. Bierman for actually checking the data to see whether or not the areas in the watershed that you're trying to model are appropriately classified, are you?

A. No. I used the national land cover data as I described, and Dr. Bierman's description of what I did was inaccurate.
Q. Anything inaccurate about the images that he showed and discussed in his direct testimony where there were misclassifications?
A. I'm not sure there were misclassifications.
Q. Did you bother to check?
A. I didn't perform that analysis.
Q. Doctor, you also offered some criticisms of Dr. Connolly's testimony that wastewater treatment plants are the dominant source of soluble reactive phosphorus that impacts water quality. Do you recall that testimony?
A. Yes.
Q. And your testimony, as I understood it, is that there is soluble reactive phosphorus in small tributaries that are not downstream of wastewater treatment plants; is that right?
A. Yes.
Q. Now, Doctor, this is not a question that you explored in your expert report, is it?
A. I explored total phosphorus in those same watersheds, and at the same time the total phosphorus data were collected, soluble reactive

phosphorus data were also obtained for those same locations.
Q. But, Doctor, you did not offer in your expert report any opinion specifically as to SRP levels in small tributaries or anyplace else, did you?
A. Within the expert report, it was total phosphorus that was described in those tributaries.
Q. So what we saw today in terms of SRP analysis in small tributaries is new analysis that you've completed in the last few weeks; is that fair?
A. It would be new analysis with existing data, yes.
Q. Let's start with your correlation analysis.
MR. GEORGE: Can we pull up State Demonstratives 415 and 414. Can we do them at the same time?
May I approach the screen, Your Honor?
THE COURT: Yes, sir.
Q. (By Mr. George) Your testimony with respect to these two exhibits, Doctor, as I understood it, is that in the 12 subwatersheds, SRP levels correspond, in your view, with poultry house density; is that right?
A. Yes.
Q. Now, let's focus for a moment on Demonstrative

415. Can we pull that one out? I notice that you -- well, first of all, this is the same format in terms of correlation analysis, poultry house density to phosphorus that we saw in your direct testimony previously in this case with respect to total phosphorus, right?
A. Yes.
Q. It's the same concept, right?
A. Same concept, yes.
Q. Using the same data in terms of poultry house density, right?
A. Yes. It would have been the same poultry house density data.
Q. The only thing different about this analysis as compared to what you testified to previously for total phosphorus is that you've now drilled down and looked at SRP as a subset of total phosphorus, right?
A. Correct.
Q. Now, I notice once again in this analysis, you've used your two-mile buffer zones around these subwatersheds, correct?
A. Correct.
Q. So once again, in order to generate the poultry house density that you correlate in this chart, you

reached out of the watershed -- the subwatershed and pulled in poultry houses that are within two miles of the subwatershed boundary, right?
A. For this particular graph, that's the case. There were others that did not that were in materials provided.
Q. Did you create any graphs on soluble reactive phosphorus that did not include these buffers?
A. Yes.
Q. And you believe you provided those?
A. I'm certain I did.
Q. Who did you provide them to?
A. To Mr. Page.
Q. But your testimony today was based upon the total poultry house density with the two-mile buffers added, right?
A. Correct.
Q. Now, Doctor, would I be correct in assuming that you have not visited any of these specific subwatersheds to examine where the samples were taken since you last testified at trial?
A. Correct.
Q. Now, did you review Dr. Sullivan's testimony in this courtroom?
A. Yes, I did.

Q. Did you see that Dr. Sullivan testified that impacts in terms of phosphorus levels in small tributaries are inherently localized and can result from a number of sources? Do you see that discussion?
A. I recall that vaguely, yes.
Q. Do you have any disagreement with that, the idea that in small tributaries, the source of phosphorus in those tributaries is an inherently localized analysis?
A. I'm not sure that I would characterize it necessarily as a localized analysis.
Q. You agree, do you not, that there are multiple potential sources of soluble reactive phosphorus within those subwatersheds beyond poultry?
A. There will be sources beyond poultry, yes.
Q. Doctor, you did not do any sampling upstream and downstream from any particular poultry farm associated with any of these defendants to support your analysis, did you?
A. I myself did not.
Q. Doctor, this particular correlation analysis that you've presented, which is Demonstrative 415, focuses on base flow; is that right?
A. Correct.

Q. Now, do you understand that, to date, the State's theory has been that poultry litter gets to streams primarily in runoff as a result of rain events?
A. That's certainly where the majority of the mass would reach streams.
Q. You also understand that other sources of phosphorus in the watershed and in these subwatersheds can contribute SRP during either base flow or high-flow conditions, right?
A. Yes.
Q. For example, Doctor, cattle can and do stand in small tributaries and deposit manure containing phosphorus directly into streams, don't they?
A. Yes.
Q. That manure can contain SRP, can it not?
A. Yes.
Q. Cattle can do this during base flow conditions, can't they?
A. They could, yes.
Q. You didn't do any investigation of the presence of cattle in these locations, did you, Doctor?
A. I did not, but I did an analysis that looked at cattle contribution in these subwatersheds.
Q. Doctor, you also understand that septic tanks

can contribute soluble reactive phosphorus to groundwater that feeds small tributaries during base flow conditions, don't you?
A. They could, yes.
Q. Now, the last time you testified, you acknowledged having found the correlation between total phosphorus levels and septic tanks; do you remember that, in these particular subwatersheds?
A. Correct.
Q. You didn't mention septic tanks in your testimony today, did you?
A. No.
Q. Now, you did discuss this idea of phosphorus during nonpoint source events, runoff events making its way into the alluvium. Do you remember that?
A. Right.
Q. And that phosphorus coming back into the system during base flow conditions. You recall that testimony?
A. Yes.
Q. Doctor, have you taken any measurements or do you have any data to support the theory that you announced here today that base flow conditions, SRP levels are explained by alluvial deposition during base flow times from nonpoint sources?

A. I have certainly seen scientific journals that have described that phenomena, so based on those descriptions, that's one of the mechanisms. And I described a second pathway as well.

Q. Did you understand my question, Doctor, was with respect to whether you had any measurements or data?

A. So I did not have measurements specific to these locations.

Q. So that's just your theory, isn't it?

A. I would say that it's more than a theory.

Q. What did you do to test that theory in the Illinois River Watershed?

A. So I guess to test that, you know, I did examine other potential contributors to soluble -- to total phosphorus from these subwatersheds and systematically ruled out these other sources, and that left poultry house operations as the one factor that would potentially explain this.

And my experience with infiltration of water, picking up materials, becoming shallow groundwater and waters coming back as base flow indicates that there is soluble reactive phosphorus and total phosphorus to be found in that base flow.

Q. The systematic analysis that you described is

your mass balance; is that what you're referring to?
A. No.
Q. Let's look at State's Demonstrative 414. This table shows the SRP concentrations in each of these 12 subwatersheds and the percentage of total phosphorus comprised by SRP in each; is that right?
A. Yes.
Q. You appreciate, don't you, Doctor, that Dr. Connolly didn't claim that wastewater treatment plants are the only source of phosphorus in the watershed? Did you understand that was his claim?
A. I think he said they were the dominant source.
Q. Do you interpret "dominant" as being equivalent with "only"?
A. Those are not equal.
Q. Is the new opinion that you offer today inconsistent with anything Dr. Connolly said?
A. Certainly -- I think it is somewhat in that there are many, many small watersheds contributing soluble reactive phosphorus, and so if one looks at the contributions of these, I'm not sure that one can readily claim that the dominant source is wastewater treatment.
Q. You're not suggesting, are you, sir, that SRP from these 12 subwatersheds is the dominant source

of SRP in the main stem of the Illinois River, are you?

A. No. There would be hundreds of watersheds that would be comparable to these that contribute the flow that one observes in the main stem of the Illinois River.

Q. Even if we expanded it out to other small tributaries which are not included in your chart, you're not offering the opinion, are you, sir, that SRP from small tributaries such as those shown on this table is the dominant source of SRP in the watershed during base flow conditions? You're not offering that opinion, are you?

A. They're a significant source.

Q. My question was dominant.

A. I guess wastewater treatment may be larger, but the contributions from these small watersheds is certainly of similar magnitude to wastewater treatment during these base flow conditions.

Q. Let's look at wastewater treatment plants. You recall that when you did your poultry house density analysis, you excluded two subwatersheds that were impacted by discharges from wastewater treatment plants?

A. Yes.

Q. And that was an appropriate thing to do in order to assess nonpoint source impacts, right?
A. Correct.
Q. Let me show you a couple of demonstrative exhibits.
MR. GEORGE: May I approach, Your Honor?
THE COURT: Yes, sir.
Q. (By Mr. George) Doctor, I've provided you a demonstrative that Dr. Connolly explained during his testimony from that same stand, Tyson Demonstrative 257, which is a replot of some data that Dr. Olsen used in what he's called his gradient analysis teasing out the differences between small tributaries with and without wastewater treatment plants.
When you reviewed Dr. Connolly's testimony in preparing to come in and rebut it in this courtroom, did you see his discussion of this demonstrative?
A. I did see it. I'm not recalling the details at the moment as I sit here.
Q. Doctor, the bottom chart, that's what I want to focus on because it relates to soluble reactive phosphorus. The bottom chart shows soluble reactive phosphorus concentrations in small tributaries. Do

you see that?
A. Yes.
Q. It's got it broken down by high flow and base flow.
A. Yes, I see it.
Q. And you'll see that there's a reference to blue bars and red bars. And then down at the bottom, there is a reference to HFS 04 and HFS 22. Those are the two subwatersheds, small tributaries impacted by wastewater treatment plants that you removed from your analysis, right?
A. Yes.
Q. And you'll see that it reports there the base flow concentration for HFS 04, that small tributary station, as 1744 micrograms per liter. Do you see that?
A. Yes.
Q. Then you'll see the report for the base flow concentration at HFS 22 as 1191 micrograms per liter. Do you see that?
A. Yes.
Q. Let's compare those two values to the values shown on your chart, which is Demonstrative Exhibit 416. Let me go back to that.
Doctor, for these small tributaries that

are not impacted by wastewater treatment plants, what did you report as the average soluble reactive phosphorus concentration in micrograms per liter?
A. That would be 27.
Q. You'd agree, would you not, Doctor, that the SRP concentrations in these small tributaries impacted by point sources that we discussed a moment ago are higher than the unimpacted small tributaries by several orders of magnitude?
A. Maybe by not several, but by an order of magnitude, yes.
Q. Twenty-seven as compared to 1191 and 1744, right?
A. So not quite two.
Q. Two orders of magnitude, almost two orders?
A. Almost two.
Q. Let's go back to Demonstrative 257 from Dr. Connolly. And you'll see that in Dr. Connolly's analysis, under the small tribs base flow conditions that the red bar for the nonwastewater treatment plant impacted sites, is, it appears to me, about at either 25 or -- around 25 micrograms per liter. Do you agree with that?
A. That's in that ball park, yes.
Q. That's pretty close to the 27 micrograms per

liter that you showed on your table, right?
A. Correct.
Q. Let's look at how those small tributaries -- let me back up for a second. You'll see there's a reference to USGS data?
A. Yes.
Q. Okay. And it's divided again by high flow and base flow?
A. Yes.
Q. And what's the reported -- approximate it as best you can -- base flow concentration for soluble reactive phosphorus at the USGS stations?
A. Looks like that's on the order of 140.
Q. Again, that is considerably higher than the average of 27 micrograms per liter you report for these small tributaries, right?
A. Yes, it's higher.
Q. Dr. Engel, where are the USGS stations in this watershed? Are they in small tributaries or are they in larger streams and rivers?
A. They would tend to be on the larger streams and rivers.
Q. Are you aware that many of the USGS stations in this watershed are located in the scenic river portions of the watershed?

A. Yes.

Q. So, Doctor, if we look at the SRP concentrations in the larger rivers measured by USGS under base flow conditions, the small tributaries that you focused on in your analysis clearly don't account for those concentrations, do they?

A. They would certainly account for a portion of the concentrations.

Q. Isn't it, in fact, true, Doctor, that these small tributaries and the concentration of SRP that's reported in them, according to your analysis, actually serve to dilute the phosphorus concentration in the larger rivers when they join?

A. I'm not sure that -- I'm not sure about that. I would have to think about that.

Q. Let me help you think about it. If we take a river that has 140 micrograms per liter of soluble reactive phosphorus during base flow conditions, and you have a small tributary that ultimately feeds into that river phosphorus that is 27 micrograms per liter, that river, that small tributary actually dilutes the phosphorus concentration in the larger river in my analysis, right?

A. So based on your description, there would be some dilution, yes.

Q. So, Doctor, you're not seriously offering the opinion in this court, are you, that the 27 micrograms per liter of phosphorus on average in these 12 small tributaries explains the phosphorus concentrations that we see that are far beyond that in the main stem of the Illinois River?

A. So they would explain some portion, and so they would explain on the order of 27 micrograms per liter in that flow is from nonpoint sources.

Q. Doctor, one other question, if we can go back to your chart, which is Demonstrative -- somebody give me a number -- 414. I want to talk about the units of value that are reported.

You report base flow SRP concentrations in micrograms per liter, right?

A. Yes.

Q. What would the 27 micrograms per liter be if we converted it to milligrams per liter?

A. So the 27 would become .027 milligrams per liter.

MR. GEORGE: May I have a moment to confer, Your Honor?

THE COURT: Yes.

(Off-the-record discussion was had.)

MR. GEORGE: Your Honor, I pass the

witness.

THE COURT: Redirect.

MR. PAGE: Thank you, Your Honor.

Could we leave Tyson Demonstrative 257 up, please. This is the one with the bar charts that was from -- the one I can remember the best, so we better start with that one first.

REDIRECT EXAMINATION

BY MR. PAGE:

Q. Dr. Engel, we just heard testimony on this particular chart. Are there more than 12 small watersheds in the IRW contributing to the Illinois River?

A. Yes, there would be on the order of several hundred the size of these small watersheds.

Q. And, sir, would you say that the majority or somewhat less than majority of these small watersheds are influenced by wastewater treatment plant?

A. So the -- there would be very few of these small watersheds influenced by wastewater treatment plant discharge.

Q. So we're not just talking about 12 possible small watersheds that would contribute nonpoint source SRP in the IRW, are we, sir?

A. No. There would be on the order of several hundred.
Q. How many of those several hundred actually are influenced by wastewater treatment plant?
A. I'm not sure of the number, but it would be, you know, certainly less than 50, less than 20.
Q. Now, let's talk about these two subwatersheds that were left out of your 12 watershed analyses. That's HFS 04 and HFS 22, correct, sir?
A. Yes.
Q. And Mr. George asked you some questions about the level of concentrations of -- in those two subwatersheds, correct?
A. Yes.
Q. And they are, those in the base flow, much higher than the average concentrations from the other 12; is that correct?
A. Correct.
Q. Now, have you evaluated the land uses relating to those two watersheds, that is HFS 04 and 22?
A. I have evaluated them, but I am not recalling what the land uses are at this point, but they did include wastewater treatment plant discharge.
Q. Did they also include poultry houses?
A. They would have included some poultry houses as

well. I don't recall how many at this point.
Q. So is it your understanding, sir, that when you originally selected these, you were trying to get watersheds with poultry houses but without wastewater treatment?
A. That was the goal of the selection, yes.
Q. Does that jar your recollection as to whether or not these two subwatersheds also had poultry houses within them?
A. They would have had some; I just don't recall the specific numbers.
Q. Would you expect those poultry houses to have contributed to these phosphorus concentrations that are shown on Tyson's Defendant Demonstrative 257?
A. Yes. The poultry operations that went with those houses would contribute some portion of this phosphorus.
Q. Okay, sir. Now, I want to change topics with you. I want to ask you about the questions that Mr. George asked you about recalibration after you discovered the HRUs. I want to make sure the record is clear. You recalibrated one time, that is recalibrated one time after you discovered the problem with the first calibration, correct?
A. Correct.

Q. Did you ever then recalibrate your model when you ran the different scenarios?

A. No. The coefficients remained the same for all the scenarios.

Q. When you validated your model, did you recalibrate it?

A. No. It remained -- the coefficients remained the same for that case as well.

Q. Now, sir, there was a lot of discussion about whether or not your routing model was constrained at all. Were there any constraints on your routing model?

A. Well, the inputs from the wastewater treatment as well as from the GLEAMS model provided constraints for the inputs into the routing model, so there were constraints on that side of things.

Q. Would you explain for the court how that is a constraint on how much calibration would be allowed for your routing model, that is the inputs that you used.

A. Yes. So the wastewater treatment came from observed wastewater treatment inputs, so those were well known. The GLEAMS model had been calibrated and validated prior to being used to provide inputs to the routing model, so the amount of phosphorus

delivered to the edge of the fields was also well established. So those provided a boundary condition as to how much phosphorus was being input into that part of the routing equation.

The other constraints that were imposed logically were that, you know, one would not expect, as we discussed in prior testimony, that there would be significant amounts of phosphorus moving to these gauging stations on days in which there's no flow. So there were other looks by myself at the model outputs to understand, you know, did this make sense. And so that constraint, if you will, was also imposed.

Q. If you weren't using actual GLEAMS output from conditions in this watershed or actual loading records from wastewater treatment plants in this watershed, would it be then reasonable to constrain the calibration process?

A. At that point, yes, it would be reasonable to do so because you would not expect inputs of nonpoint sources on days in which there is not rainfall. It would be reasonable to constrain the wastewater treatment plant discharges as well. So, you know, so one would have to impose those constraints themselves since the model had been

decoupled, as I've talked about earlier.

Q. Does the coupling process itself, that is that you coupled the routing model with a model of nonpoint source runoff from your GLEAMS along with actual data from wastewater treatment plant discharges in the IRW provide a constraint on your calibration process when you run through the shuffling --

A. SCE.

Q. Shuffling coefficient?

A. Complex evolution.

Q. Complex evolution, thank you, sir.

A. So, yes, it would have provided that constraint.

MR. PAGE: Now, could I get a little more help again, please, with Demonstrative 382.

Q. (By Mr. Page) This is a demonstrative that Mr. George showed you. And I notice that when he asked you if this accurately depicted your model and its relationship to both the lake and GLEAMS and wastewater treatment plant that you had some hesitancy; at least that's what I perceived.

What is it about this flow diagram that would not be representative of your IRW model?

A. Well, so the hesitancy here was that the GLEAMS

and the wastewater treatment plant inputs, the figure seems to imply that those go directly to the river. Those go to the edge of field, those go to the locations of wastewater treatment plants discharge. So there are many, many miles of streams, small streams and channel networks. So those inputs go to that location, and so it's that phosphorus in that network that's the phosphorus accumulation term in the routing model.

MR. PAGE: Your Honor, may I approach that board, please?

THE COURT: Yes.

Q. (By Mr. Page) Dr. Engel, I want to know if I'm understanding it correctly. Is the problem with this depiction is they've got a intermediary step here of P to the river?

A. Yes, the P to the river is probably better described as phosphorus to the stream and river network system. So it's more than just to the river.

THE COURT: Of course, Doctor, that's your term used on your spreadsheet, correct, P to river?

THE WITNESS: Yes, in the spreadsheet, that is my term.

THE COURT: You said a couple of times

that, in your view, that's more accurately stated as P to the stream network.

THE WITNESS: Yes. So the shorthand in the spreadsheet was P to river, you're correct.

THE COURT: Go ahead.

Q. (By Mr. Page) So to understand the clarification you just made with the court, is it fair, so I understand the process here, the routing model really starts up here, picks up the GLEAMS in the wastewater treatment plant, then routes from those processes all the way to the lake?

A. Yes, it would.

Q. Dr. Engel, can we look at Demonstrative 417 State of Oklahoma, which is the S&P inputs that Mr. George reviewed with you. State of Oklahoma 417.

Dr. Engel, Mr. George, I believe his questions focused on whether there was a pattern here that show that there was a similar pattern between the model with the actual GLEAMS and wastewater treatment plant inputs to that of S&P on a yearly basis, correct?

A. Yes.

Q. Now, is there something about runoff modeling in a watershed that would indicate that you would

have a similar pattern over these years if you use either inputs from the GLEAMS model or the S&P inputs that Dr. Bierman used?
A. Well, because the S&P inputs were of similar magnitude and similar spacing as the inputs provided by GLEAMS and wastewater treatment, and since phosphorus is transported through the stream and river network system by flow, flow is going to be important in that transport process.
Q. So whether you used the S&P inputs for 2004 or your GLEAMS inputs for 2004, both those model runs use the actual hydrological inputs from the IRW for 2004?
A. Yes. So both of those would have used the observed flow in order to transport that phosphorus. So I guess, again, you know, this represents this decoupling process gone awry a bit as well because the S&P doesn't know dry days versus wet days. So when no one imposes that constraint, you can put those values in and you'll get similar results, as we see.
Q. But the key factor for moving, whether it's S&P phosphorus or GLEAMS phosphorus, is the amount of water falling on that watershed in a particular year, correct?

MR. GEORGE: Objection, leading.
THE COURT: Sustained.
Q. (By Mr. Page) What would be the single key factor, if you were going to select one, as to movement of phosphorus within the watershed in a particular year?
A. Well, I guess there are two that are related, so rainfall and the amount of flow are closely coupled together, and those are going to determine year in, year out, within bounds, the amount of phosphorus that's likely to be transported.
Q. I suppose we could have made a chart that had a daily fluctuation basis rather than summarizing by year. Now, did you evaluate what the daily fluctuation difference was between just the S&P and your GLEAMS inputs?
A. I did look at that variation on an annual basis. That annual amount is approximately the same between S&P summed up and GLEAMS nonpoint source and wastewater treatment summed. So those two sums are similar.
Q. I think you misunderstood my question. Did you look at the differences on a daily basis for the delivery to the lake between whether you use S&P or GLEAMS output?

A. Yes, I did. And so what I found for the S&P results, then, were that using the S&P as the input, the average daily variation was about 187 percent. So that on any given day, there was substantial variation in what my model predicted and what my model with the S&P serving as the phosphorus inputs predicted.

Q. When you consolidate those daily into annual, does that minimize, then, the daily differentials?

A. Yes, because on some days, it overstated the amount moved; on other days, it understated that. But on an annual basis, as we can see here, it provided something that was somewhat similar.

Q. Now, Mr. George spent a lot of time talking about R^2 with you and comparing Dr. Bierman's R^2 and your R^2. And several times, maybe a dozen times, you said that's not the whole story.

I'm going to ask you the question now: Is there a problem with relying upon R^2 as to determine -- as the sole basis to determine the reliability of a model?

A. Well, I think first we have to step back even before we generate any model outputs and are able to compute R^2, in that there has to be reasonable data going into the model.

So when we have the S&P being used as an input that doesn't reflect whether phosphorus should get to the stream that day or not because there was no rain, so we have logic problems with this that way before we ever compute R^2 would make a modeler say, well, this can't make any sense.

Q. So would a modeler put in data that indicates there's a delivery on a dry day and then just go and proceed to determine whether it has a good R^2?

A. No. They would never get that far, so they would make sure that the data going in makes sense, has some physical reality. So it starts there.

Q. Are there other issues with this relying on R^2 values?

A. Yes. So beyond that, one would need to look at the modeling routing model coefficients that were obtained to see if those made sense.

As I recall with the S&P input of -- you know, the values used indicated, again, that there was substantial phosphorus moving on days in which there was no flow. So, again, because there was not a constraint of that value and just a blind fitting of a model to that resulted in something that didn't make sense physically.

Q. Are there any other issues?

A. Well, certainly one would also, as I did, look at the amount of phosphorus that's accumulating in the stream. So there are checks of that nature that would allow one to see, you know, does this have any grounding in reality.

I guess one other point that I missed even on the front side of this was that, again, you know, if there are these -- if -- the observed data that's used in developing the routing model, one has to have some belief in the inputs that are used to create that relationship.

You know, making up big arbitrary values and then forcing the equation to calibrate doesn't make sense, and it doesn't make sense that for those big values the observed data would have been the same. So there are a number of places here where one would really want to step through and make sure that all of these things were in order and not just simply rush to the R^2 as the determining value.

Q. Have you ever seen any publications, either textbooks or peer-reviewed literature, where the modeler is warned that they should not rely on R^2 to be the determinative value of model reliability?

MR. GEORGE: Objection, Your Honor, calls for hearsay. There's a learned treatise --

MR. PAGE: I asked if he's aware of it, Your Honor. I guess we'll go to the next question.

THE COURT: He can rely on hearsay, although, frankly, we've been through the importance of R^2 over and over in this trial. And it's clearly not the sole factor. Let's move on.

MR. PAGE: Thank you, Your Honor.

Can I have a minute, Your Honor?

THE COURT: Yes.

MR. PAGE: Thank you.

Q. (By Mr. Page) Do you remember when there was some -- what Mr. George characterized as substantial changes to the coefficients where you have a number of 205 and you had nine zeros in front of it and then they double it to 410?

A. Yes.

Q. Given the fact you have nine zeros in front of 205, is doubling 205 with nine zeros in it, decimal point and nine zeros, really a substantial change?

A. It certainly wasn't as substantial as some of the changes that Mr. Bierman made. If you recall from this morning's testimony, at least if I recall correctly, for the nonpoint source example, that change was not double; it was a factor of nearly 1,000 that the change was in that coefficient. So,

you know, so doubling versus a factor of 1,000, that's quite a bit different.

MR. PAGE: Your Honor, I pass the witness.

THE COURT: Recross.

MR. GEORGE: No, Your Honor.

THE COURT: Very well. May this witness be excused?

MR. PAGE: Yes, Your Honor.

THE COURT: Thank you, sir. Give you, you say, 10 minutes?

MR. GEORGE: Yes, sir. Your Honor, the defendants call Dr. John Connolly.

THE COURT: He's been sworn as -- frankly, as Dr. Engel. My general practice is not to reswear.

Doctor, you recall you've been previously sworn. You remain under oath.

THE WITNESS: Yes.

THE COURT: Mr. George, you may inquire.

MR. GEORGE: Can we pull up Defendants' Joint Exhibit 6097.

<u>DR. JOHN CONNOLLY</u>,

having been previously duly sworn, was called as a

witness and testified as follows:

DIRECT EXAMINATION

BY MR. GEORGE:

Q. Dr. Connolly, you've been present in the courtroom today during the testimony of Dr. Engel, have you not?

A. Yes, I have.

Q. And did you have an opportunity to hear Dr. Engel's testimony regarding your analysis as shown in Defendants' Joint Exhibit 6097?

A. Yes.

Q. And could you, just to give us a reset -- would you like a copy?

A. Sure.

Q. Doctor, to give us a reset, could you just generally frame the purpose and thrust of the analysis that's shown in Defendants' Joint Exhibit 6097.

A. This analysis was meant to compare the distribution of concentrations in the Illinois River at Tahlequah to the average value of the wastewater treatment plants.

MR. PAGE: Your Honor, my belief, this is a revised version that's been put on the screen. It is what was marked DJX6097r. Mr. Green, during

Mr. Connolly's direct examination, tried to offer this. And I objected, and you sustained, because this work was done after his deposition.

THE COURT: What does the record reflect regarding its admission?

MR. PAGE: The one that was on the screen was not admitted. Now, this one that's now up is 6097 is the one I examined Mr. -- excuse me, Dr. Engel on -- just a mistake?

MR. GEORGE: I believe it is. And, Your Honor, we can correct this. Can we pull up whatever version was used in the examination of Dr. Engel earlier today?

MR. TODD: It's what's up.

Q. (By Mr. George) Dr. Connolly, can you confirm that the exhibit I've handed you is the same version of Defendants' Joint Exhibit 6097 that's on the screen?

A. It is.

Q. Doctor, can you continue with explaining the general point and thrust of this analysis.

A. The point and thrust of the analysis was to look at sort of the central tendency of the loads in the river as compared to the central tendency as indicated by the line from the wastewater treatment

plants.

I believe that Dr. Engel attempted to compute a mean value from this distribution and concluded that he got a number, I don't remember precisely, 150 or something.

Q. Doctor, do you think that's an appropriate comparison that was made by Dr. Engel?

A. I do not, for several reasons. One, we're sort of looking at apples and oranges here in terms of what the wastewater treatment plants represent versus what this data represent.

These data represent a fairly intensive sampling of the river of 78 data points. There's much less data in the wastewater treatment plant number. And we have no sense of variability in the wastewater treatment plant number. It's just a single value, as we see the variability in the river.

And, in fact, the difference in the averages that Dr. Olsen pointed out are actually due pretty much just to the last bar to the right which represents three samples that were at much higher load than the rest of the database.

And the reason there are three values at those loading numbers is uncertain. Could very well

be due to wastewater treatment plants. I mean, wastewater treatment plants have upsets, they can reflect an upset of the wastewater treatment plants. It's just not clear.

In fact, if you don't include those three values, the average of the rest of the data is lower than the average of the wastewater treatment plant.

I think the last point here is that any real comparison between means has to be a statistical comparison to determine whether there's a statistically meaningful difference, not just simply a difference.

Q. And, Doctor, Dr. Engel during his testimony came to the conclusion, based upon his review of this average in comparison to the rest of the data, that 40 percent of the soluble reactive phosphorus during base flow comes from nonpoint sources. Do you recall him offering that opinion?

A. Yes, I do.

Q. Do you agree with that?

A. I do not. I don't think you can make that conclusion from the simple comparison of the numbers that he did.

Q. Let me discuss one other exhibit.

MR. GEORGE: May I approach, Your Honor?

THE COURT: Yes.

Q. (By Mr. George) Doctor, I've placed in front of you an exhibit that is already in evidence. It's Defendants' Joint Exhibit 6094. Do you recognize this exhibit as a figure from your report?

A. I do.

Q. And does this exhibit relate to your analysis of soluble reactive phosphorus concentrations within the stream and river network?

MR. PAGE: Your Honor, this exhibit was not examined on rebuttal. This is outside the scope of rebuttal; therefore, it's improper.

THE COURT: It's within the scope insofar as it goes to this issue of whether SRP is from wastewater treatment plants or what portion or if there's a significant portion of SRP from nonpoint sources. Go ahead.

Q. (By Mr. George) Dr. Connolly, this figure comes out of your report, correct?

A. Yes, it does.

Q. You prepared it, or it was prepared under your direction, correct?

A. Yes, it was.

Q. Now, you heard Dr. Engel's testimony today regarding the concentration -- average concentration

of 27 micrograms per liter of phosphorus -- SRP phosphorus in these small tributaries?

A. Yes.

Q. Using this chart and the data that you've plotted for soluble reactive phosphorus in the streams and tributaries that are shown, can you describe where that value would fit in terms of explaining the SRP levels that we see?

A. As Dr. Engel indicated, 27 micrograms per liter is .027 milligrams per liter, which is the scale that's used here on the Y axis. So it would plot very close to the X axis, the horizontal axis. It would be between the second and third tick up.

So if you can imagine drawing a line across the second to third tick up, you can see that it is very low compared to the measurements in Spring Creek and Osage Creek and in the Illinois River as well.

So, in fact, in the Illinois River, it about equals perhaps the fourth point from the left. And you can see after that, it gets overwhelmed by higher concentrations that appear to be due to influence of wastewater treatment plants.

THE COURT: What about the argument advanced by Mr. Page here that in wastewater

treatment plants, there are hundreds of smaller subwatersheds, and the aggregation thereof explains a significant portion?

THE WITNESS: No matter how much water you have coming in at 27 micrograms per liter, it can't make water any more than 27 micrograms per liter.

THE COURT: In terms of concentration.

THE WITNESS: In terms of concentration.

THE COURT: Mr. George.

MR. GEORGE: Thank you, Your Honor.

Q. (By Mr. George) Dr. Connolly, do you draw any conclusions based upon the analysis that we just walked through in terms of the impact of these small tributaries that Dr. Engel has focused on in terms of SRP within the Illinois River?

A. They have a small impact in comparison to the levels that we see, which I believe are due mostly to wastewater treatment plants.

MR. GEORGE: Your Honor, I have been told that this exhibit, although discussed with Dr. Connolly during his testimony, was not formally moved into evidence, and so I would like at this time to offer Defendants' Joint Exhibit 6094.

THE COURT: Any objection?

MR. PAGE: I object for the same reason I

mentioned earlier.

THE COURT: I agree. This is a bit late to be admitting these documents. Sustained.

MR. GEORGE: Thank you, Your Honor. I pass the witness.

THE COURT: Cross-examination.

MR. PAGE: Thank you, Your Honor.

THE COURT: And he came in at eight minutes.

MR. GEORGE: I sensed I was actually on a clock.

MR. PAGE: I think that's a challenge.

CROSS-EXAMINATION

BY MR. PAGE:

Q. Dr. Connolly, looking at Defendants' Joint Exhibit 6097, the first one you looked at --

A. Yes.

Q. -- this is your exhibit, correct?

A. Yes.

Q. This is your data. This is your data that you selected for base flow data, correct?

A. Yes.

Q. And so are you now telling us that you made a mistake when you included these points over here on the right-hand side that get up to base flow as part

of CFS flow of up to 10,000?
A. No, I'm not. No.
Q. So you're still conceding that's base flow, correct?
A. Yes.
Q. Are you contesting the fact that, using your own data, Dr. Engel was able to calculate that 40 percent of the total phosphorus came from nonpoint sources?
A. He was able to calculate a mean value. The conclusion he drew from that mean value that 40 percent of what was coming in was coming from nonpoint sources is incorrect.
Q. Dr. Connolly, I want to look at your other demonstrative here. I guess we'll call it DJX6094.
Sir, you're not suggesting, are you, sir, that there are only -- of all the subwatersheds in the IRW, all of them, if you average them together, would have a concentration of SRP of 27 micrograms per liter? You're not telling the court that, are you, sir?
A. I don't think anybody can tell the court that. What we have are the data that were measured, and the data that were measured indicate that these tributaries have 27. So without any additional

data, there's no reason to think that it would be anything but 27.
Q. Oh, really? So you say you just take the 12 that Dr. Engel used for his -- his poultry house density analysis, and you would assume that those 12 are representative of all the concentrations of all the subwatersheds in the IRW from nonpoint source? Is that your testimony?
A. I would assume that the plaintiffs chose those to be represented.
Q. Well, sir, let's just look at your Spring Creek analysis. Do you see that, sir?
A. Yes.
Q. Do you see RS000348?
A. Yes.
Q. What is the concentration at that location?
A. Appears to be about .09.
Q. .09. There's no wastewater treatment plant contributing at that location, is there?
A. There is not.
Q. Wouldn't that be some evidence to indicate to you that the 12 watersheds are not representative of the concentrations from all of the subwatersheds in the IRW that do not have wastewater treatment plant?
A. I am not claiming that every subwatershed has

27 micrograms per liter. In fact, the 12 subwatersheds that Dr. Engel showed have a variety of concentrations that averaged 27. I think the average is the appropriate number when you're aggregating up. I think we'll find some that are as low as 7 in that dataset and one year that is as high as .9.

Q. Those different flows would contribute a lot to the amount of actual phosphorus as being contributed to the IRW; is that correct?

A. I don't understand the question.

Q. You wouldn't just look at concentrations; you would also look at flows, would you not, to determine impact?

A. Yes.

MR. PAGE: Thank you, Your Honor, I have no other questions.

THE COURT: Redirect.

MR. GEORGE: None, Your Honor.

THE COURT: May this witness be excused?

MR. GEORGE: He may, Your Honor.

THE COURT: The plaintiff may call its next witness.

MR. PAGE: Thank you, Your Honor. We call Dr. Wells.

THE COURT: Dr. Wells, you, too, have already been sworn. Let me remind you you remain under oath, sir.

Mr. Page.

MR. PAGE: Thank you, Your Honor.

DR. SCOTT WELLS,

having been previously duly sworn, was called as a witness and testified as follows:

DIRECT EXAMINATION

BY MR. PAGE:

Q. Good afternoon, Dr. Wells. There's a decent chance we may still get you on your plane. I don't know, with the security.

A. I don't think so.

Q. You don't think so? Okay. No OJ Simpson in the airport today for you. Okay, sir.

Dr. Wells, did you review the testimony of Dr. Bierman in this case in preparation of the rebuttal testimony you're going to give today?

A. I did.

Q. I want to review with you, sir, some of that testimony, a few items. The first one is -- the area I want to discuss with you is Dr. Bierman's testimony that the version of CE-QUAL-W2 model that used -- that was used for Lake Tenkiller was not

ready and not tested for modeling.

MR. PAGE: Can we look at Demonstrative testimony slide 433, please.

Q. (By Mr. Page) Did you find that, Doctor?

A. Yes.

Q. "QUESTION: Did Dr. Wells use the official released version of CE-QUAL-W2 for his evaluations in this case?

"ANSWER: No, he did not.

"QUESTION: What type of model did he use?

"ANSWER: Well, he used what's called a beta version.

"QUESTION: What is your understanding of the differences or changes between this beta version used by Dr. Wells and the official released version at that time?

"ANSWER: There was a pretty long list of enhancements and bugs in the transition from the official released version to the beta version, but the enhancement that's most relevant to Dr. Wells' use of the model in this case is that the beta version was given the capability to exploit computers with dual processors, and it allowed it to run much faster."

Now, do you, Dr. Wells, believe that your

model, using the lake model, using the beta version, affected the results of your model?
A. No.
Q. And why is that?
A. First of all, the code itself, I'm one of the keepers of the code, so I'm responsible for releasing the code and updating the code. We've been working with the Corps of Engineers for many years in code development. But in this particular case, what has been inferred by Dr. Bierman is that there was some lack to the model because it was a beta version of CE-QUAL-W2.
And I should mention that Dr. Bierman stated in this demonstration that there were many enhancements and bugs from the transition from the official released version to the beta version; that wasn't true. In fact, we released the official released version in September of 2008, and it essentially was exactly the same model as what was used in the Tenkiller model.
So the released version, what we used in the Tenkiller model, there were no specific bugs or enhancements during that period.
Now, since September 2008, Dr. Bierman could have tested the released version to the beta

version, because his expert report wasn't due until January of 2009, but he didn't do that.

Q. Well, sir, do you believe that the version of -- the beta version is as reliable as the released version?

A. Yes, I do.

Q. Now, was this beta version that you used -- and I guess you designated it as a beta version because you keep the model, correct?

A. That's correct.

Q. You decide when it becomes officially released, correct?

A. That's correct.

Q. Was this beta version that you used for Lake Tenkiller modeling tested in some other watershed or application other than Lake Tenkiller?

A. Yes, it was tested before we applied it to Lake Tenkiller. We always compare it to the previous version, which was version 3.5, to a whole test suite of different water bodies.

For example, we tested it to Lake Roosevelt in Washington. We tested it to Long Lake in Washington. We tested it to the Spokane River in Washington. Croton Reservoir in New York, Bluestone Reservoir in West Virginia, the Lower Columbia

Slough in Portland, Oregon, as well as the Dead Sea. Also, prior to its release, the Corps of Engineers tested it on the Missouri River.

So we did extensive testing of this before we applied it to Tenkiller Reservoir. Again, essentially the beta version that was used for Tenkiller was the same model that was released in September of 2008.

Q. Did all these tests that you just mentioned provide any information to you concerning the reliability of the version of the model that you used in this case?

A. Yes. We were testing model results for all those test cases that I outlined, and so we basically compared the updated version of the model to the prior version of the model, looking for differences.

Q. So all of the enhancements that were made from version 3.5 to 3.6, even the beta version of 3.6 which you used, were they part of the beta version that you used?

A. Yes. There were about 20 enhancements that were made from version 3.5 to version 3.6.

Q. Now, in front of you, sir, you should have a document marked Demonstrative 418, and actually it's

several pages, it starts 418a and goes through consecutively lettered to 418h. Do you have that, sir?
A. Yes, I do.
Q. Are you familiar with this document?
A. Yes, I am.
Q. What is it?
A. This is -- the W2 model is a public open source model that is available to anyone, including anyone here in the courtroom. And I maintain a list of bug fixes and enhancements in the model since its release. So this is a list of fixes or enhancements that have been made since the model was released in September of 2008.
Q. Now, you're familiar with each one of these bug fixes or enhancements, correct?
A. Yes.
Q. In your opinion, sir, do any of these enhancements have an impact on the reliability of the model that you used for Lake Tenkiller?
A. No, they don't. And, of course, with any piece of software that you release, there are always fixes and updates. And in this particular case, if you looked at the -- there were a total of, looks like 20 different fixes or enhancements since it's been

released in September of 2008. Even these fixes or enhancements would not have affected the model results.

Q. Well, briefly, can we go through these and could you explain to the court the type of fixes or enhancements that are described here that have occurred to this model since it was released?

A. Just as an example, as you can see in number one, we specify whether it's made in the W2 code or preprocessor or GUI preprocessor. And only those that would be related to the W2 model itself would have affected or potentially affect running of the Tenkiller model.

And so the first one is for the turbulent kinetic energy model one, there was an incorrect allocation of a variable as an INTEGER or REAL. In this particular case, we didn't use the TKE1 model in Tenkiller, so that particular bug fix would not have affected the model.

Q. Continue, sir.

A. If you go down to No. 2, this has to do with the PIPE algorithm. And this wasn't a bug fix; it was just updating the code and making it more concise. We didn't use the PIPE algorithm in the Tenkiller model, so that was not an issue.

Q. What about -- so the first two didn't -- those fixes didn't even apply to the application for Lake Tenkiller, am I correct?
A. That's correct.
Q. What about No. 3?
A. That's just updating the user manual because there was a typo in the user manual.
Q. Does that have any impact in the model's use?
A. No.
Q. What about No. 4?
A. Four has to do with a very specific unique case that if someone wanted to do a temperature model only and read in a longitudinal temperature file, that there was some problem reading that in when a certain variable is declared as off. This particular unique case was not a problem with the Tenkiller model.
Q. Why is that?
A. Because we didn't use a longitudinal profile input file.
Q. What about No. 5?
A. This just has to do with output from the model. This has to do with using TECPLOT as a graphics animator. In some cases where the water body -- you had multiple water bodies, the

output format had problems in the TECPLOT, which is another piece of software. So we fixed the output format so that it would be compatible with another piece of software.

Q. Did that have an impact on the Tenkiller modeling?

A. No.

Q. Was that used in the Tenkiller modeling?

A. We did use TECPLOT to animate, as I showed during my direct testimony, but we only had one water body, so it did not affect the format.

Q. What about No. 6?

A. Six has to do with epiphyton or periphyton in the W2 if you use vertical profile data to set the initial condition. And there was a code typo that was fixed. In this particular Tenkiller model, we did not set the initial condition by using vertical profile data.

Q. So it's unapplicable, this fix, to your use of the model in Tenkiller?

A. That's correct.

Q. So did No. 6 apply to your model use in Lake Tenkiller?

A. No. This was an enhancement made to the preprocessor to output loads from the preprocessor.

Q. What about No. 7?
A. Did you just -- I'm sorry, did you mention seven? Was that what you just mentioned?
Q. No, I thought we were just talking about No. 6. I actually repeated on No. 6.
A. With regard to six, we didn't use the vertical profile data for periphyton, so that was not applicable.
Q. What about No. 7, was that used or did that -- let me ask this question: Was that change -- did it have an impact on the work you did in Tenkiller?
A. No. This was just an enhancement to the preprocessor so that the model user can actually get loads from the preprocessor before you run the model.
Q. So how does that -- what kind of enhancement is that, from a layman's point of view?
A. It just provides a table to the modeler of all the calculated loads for all the inflows, and it is a nice way to check to make sure that the model has been set up, and it's a nice table to use in reports.
Q. Does it assist the modeler in setting it up?
A. No, it really just assists the model in documenting that what you put in the model is what

you intended to put in.
Q. What about No. 8 on the second page of 418b?
A. This has to do with a code fix about gas transfer at spillways. We did not include gas transfer at spillways in the Tenkiller model, and so this bug fix did not affect the Tenkiller model.
Q. It's not applicable; is that correct?
A. That's correct.
Q. What about No. 9?
A. Number 9 is similar. It also has to do with gas transfer reaeration from dams. There was a slight bug in a formula, and that was fixed, but it didn't affect the Tenkiller model.
Q. On to No. 10, sir.
A. This just was a fix to -- in the kinetic flux algorithm in the W2 model, there was inconsistencies between what was in the user manual and the input file and in the code, so we synchronized those so that there was no inconsistencies.
Q. How would you characterize this enhancement?
A. It just corrected the W2 manual and what was expected by the model user.
Q. Did it fix a typo, using laymen's terms?
A. It would have fixed a typo in the user manual.
Q. Did it have any effect on the application in

Tenkiller of this model?
A. No.
Q. Let's look at No. 11, sir. Can you describe that.
A. Number 11 is for the preprocessor. Again, the preprocessor sometimes flags errors in the model setup. This was just fixed to prevent false errors from being flagged.
Q. Did it have any impact on the Tenkiller modeling?
A. No.
Q. What about No. 11?
A. You mean No. 12?
Q. Thank you, No. 12.
A. Again, this was just additional error checking in the W2 preprocessor to aid the model user.
Q. Does this enhancement have any impact on the Tenkiller modeling efforts?
A. No.
Q. What about No. 13, sir?
A. Thirteen was an enhancement so that people could run the preprocessor in batch mode. So you could actually send the working directory to the preprocessor in a batch file and execute it with a particular command. So this was a model

enhancement.
Q. Would this enhancement have any impact on the Tenkiller modeling results?
A. No.
Q. What about No. 14?
A. Number 14 is where we allowed the user to set the number of processors that the model user could use. And in this particular case, we got feedback from users that if they had more than two processors, sometimes the model ran slower with more processors than with fewer processors. And it was clear that many river models ran faster with one processor, so we added this to the input file.
Q. Did this have any impact on the Tenkiller modeling efforts?
A. It did not materially affect the Tenkiller results. I will talk more about this when it comes to reproducibility.
Q. What about No. 15?
A. Fifteen has to do with, again, we allowed the W2 model to be run in batch mode so you could pass the working directory to the code. So this was just an enhancement. Had nothing to do with Tenkiller.
Q. It just simplifies the running of the model?
A. Yes.

Q. What about No. 16?

A. Sixteen just allows the W2 window that comes up with the Windows version of the model to collapse so that you can actually run the model in batch mode rather than having to use a different code for the model output.

Q. Does this enhancement have any impact on the modeling outputs for Tenkiller?

A. No, it would not have changed the results of the model. If we'd had this before, it would have made the model easier to run, though.

Q. What about No. 17?

A. That's just updates to the user manual.

Q. Just updates the changes that were identified earlier in some of these enhancements in the manual?

A. That's correct.

Q. What about No. 18?

A. This is for the GUI, so the GUI is just another way to edit the inputs to the model. And so we improved the GUI. We added some more parameters to the GUI and also allowed the GUI to be run in batch mode.

Q. Does this have any impact on the Tenkiller modeling results?

A. No.

Q. What about No. 19, sir?
A. Number 19 has to do with calculations of flow over spillways or gates or pipes when you have a sloping river section. We felt this was an improvement in specifying the water surface at the end of a grid point.
This would not have affected the Tenkiller model because we didn't have any sloping river sections in our model.
Q. Finally, No. 20, sir?
A. Number 20, we all know that Windows 7 has come out, and the compiler we were using for the model before had some problems with Windows 7, so this was an update to allow the model to be run in Windows 7.
Q. This exhibit is actually a printout from a web page that you maintain for this model, correct?
A. That's correct. Anybody can download this.
Q. So these are all enhancements that you chose to provide to other users for the model you maintain?
A. That's correct.
Q. So you're very familiar with all these enhancements?
A. Yes.
Q. In your opinion, would any of them have an impact on your Tenkiller modeling?

A. Not on the results of the model, no.
Q. Now, I want to change subjects a little bit and touch on the issue concerning a model replication test and whether or not your model could pass a replication test.
Would you please look at with me, sir, Demonstrative Testimony Exhibit 434. Do you have that, sir?
A. Yes, I do.
Q. "QUESTION: And have you heard of the term 'replication test'?
"ANSWER: Well, yes. Basically that's what we did. Out of frustration, actually, that we couldn't reproduce the results, we backed up and said, let's see if we can take this model, same input file, same model, run it once on the computer and then run it again, same thing, and see if we get the same answer twice in a row. And, in fact, we tried that, and to our surprise, we got different results the second time.
"QUESTION: How significant were the differences between the consecutive model runs and your replication tests?
"ANSWER: Well, it depends on the parameter one looks at, and it depends on what point in time

and what's space on the lake. So it depends.

"But I think that really the overarching issue to me is that the scientific community would simply not -- simply accept the results from any model if the model couldn't -- if the results were not capable of being replicated. That's just not consistent with the scientific method."

Now, I've just quoted to you, Dr. Wells, testimony from Dr. Bierman in this case. Do you agree with Dr. Bierman's testimony?

A. No, I don't.

Q. Would you please explain to the court why.

A. Well, the model -- Dr. Bierman, in his testimony, talked about -- I think he used temperature as an example where he ran replicate tests, and the model tests that he ran that were in his considered materials didn't show substantial variation in temperature between multiple runs.

Q. Did you actually look at those runs yourself that were in his considered materials --

A. Yes, I did.

Q. -- where he did this replication analysis?

A. Yes.

Q. Sir, would you look with me as to Demonstrative 419. Did you prepare this demonstrative?

A. Yes, I did.
Q. Would you please explain to the court what we're looking at here.
A. First of all, let me mention that I took a spreadsheet from Bierman's considered materials which was his test run for my latest calibration, which was run 400. I assume this is the basis for what he used in his testimony about temperature variations.
And if you look on the legend, there are three graphs there, T_Wells is the original model run for the temperature leaving Tenkiller Reservoir. And then apparently Dr. Bierman ran two other runs, which are in green and red, as tests to see about reproducibility.
Q. Let me make sure I understand this. The blue lines are what?
A. The blue line would be the original run for a hundred of temperature, predicted leaving Tenkiller Dam over the period of simulation from January 2005 through September 2007. And the green and the red would be replicate runs done by Dr. Bierman.
Q. So the replication test on temperature had to do with water that was leaving Lake Tenkiller through the dam?

A. Yeah, through a spillway, powerhouse and, yeah, through the dam.

Q. Well, let me ask you this, then, sir. I notice that sometimes the chart seems to go right to the bottom, like between 300 and 500 Julian day.

A. Yeah. In this particular output file that we have written out for the W2 model, whenever there was no flow out of the dam, we set the temperature to zero, just to let people understand that the model was not predicting any temperature leaving the dam because there was no flow leaving the dam.

Q. So what does it mean by Julian day there along the X axis?

A. Julian day is just the days of the year, 1 to 365, if it's a regular non-leap year. And basically day zero or day one would be January 1 of 2005. So 365 would be January 1 of 2006, etcetera. So we're looking at, oh, close to two and a half, two and three-quarter years of simulations of temperature leaving the Tenkiller Dam. And when it goes to zero, there is no flow leaving the dam. So that's why it's going up and down significantly.

Q. What is the Y axis?

A. The Y axis is temperature. And I tried to blow this up as much as I could to have it fit on the

graph so that you could discern differences.

Q. Well, can you tell me, sir, what this analysis shows?

A. Well, if you look carefully -- I'm not sure if you can see it on the screen. If you had a higher resolution screen, maybe you could see the differences more clearly. But whenever you see red or green peeking out behind the blue, there's a difference between the replicate run and the run that I submitted to Dr. Bierman in my considered materials. There you go.

And so in this particular case, you see a little bit of -- in this image that's on the screen a little bit of green and a little bit of red. Whenever those pop up, like right there, it shows there's a difference between the tests that he did.

Now, it shows that the numbers are not exact to the nth decimal point, but the model results are all the same. They do not predict something different. And there are many reasons why there might be even small variations between these replicate tests that we investigated.

Q. Do you have an opinion as to why there would be minor variations such as we're seeing here?

A. Yes. There are probably five reasons, some of

which are not independent from one another.
Q. What are those?
A. First of all, one reason could be if a modeler compiles the code on their own using their own Fortran compiler, they could make mistakes in setting up the compiler. When we see differences in reproducibility, sometimes it's because of inexperience of the model user in not knowing how to do the Fortran compiler setup correctly. So that's one.
Q. Are there any others?
A. Yes. Also, we found that when using the multiple processors, in Fortran we use a type of code called OpenMP, O-P-E-N, M-P, which allows the code to use multiple processors.

Now, when we did the Tenkiller model, we used Intel compiler version 10. Intel produces a compiler that takes our instructions and produces an executable.

And during that period of time, Intel was -- this may be a little technical, but they were what they call statically linking the OpenMP compiler routines into the executable, which means that when you compile the code for a specific PC or on your own PC -- you didn't understand me?

Q. No, I'm going to let some other people cross-examine you on that point.
A. What it did is it would work well on that particular host PC. When you conveyed it to another PC, it's possible, then, that you're getting some slight replication errors because you didn't compile the code on that host PC.
Now, since then, in version 11 of the Intel compiler, they've changed how they dealt with those OpenMP commands, and they no longer, as a default, allow the static linking.
So what they're doing now is what they call dynamic linking -- I'm sure everybody is with me -- which basically means that when someone executes code on their own PC, it generates these commands for the local PC rather than for the PC that it was compiled on.
Q. So these minor differences in compiler methods would account for the minor differences we're seeing here, perhaps?
A. Yes. Then there's some related issues. Once you have these minor differences, you get round-off error in terms of the precision of the numbers that you output to an output file. You also can get differences in the output, exact output time that

the model is outputting. So there's some issues associated with that.
Q. Now, what you've documented on this Demonstrative 419 are the differences that Dr. Bierman came up with when he did the replication analysis, correct?
A. Yes. Based on his direct testimony, he talked about the temperature issue, and this apparently is what he was referring to.
Q. Do you have an opinion as to whether the differences that are documented by Dr. Bierman and then shown on this exhibit have any impact on the results of the water quality modeling for Lake Tenkiller?
A. No, I do not. Also, for the reason that even if you look at reproducibility of actual temperature measurements, in the state of Oregon, they claim that you cannot measure temperature to within .3 degrees C. If you took two different thermometers and put them in the water body, if there's a difference between .3 degrees C, they relate that to just the lack of reproducibility in a normal temperature measurement.
Q. I want to rewind that last question again. I asked you whether you had an opinion as to whether

these differences, I think -- maybe I didn't follow my question too well. But what I thought I asked you was: Do you have an opinion as to whether these differences that you've documented here would have an impact on the modeling results?

A. Yes, I have an opinion.

Q. What is that opinion?

A. That these are of such a small consequence that they would not have affected the results of the model.

Q. I want to change topics on you, Dr. Wells, and I want to talk to you about Dr. Bierman's opinion where he claimed that there were problems with the SRP data that Dr. Engel provided you, and that those problems affected your modeling results.

Would you please look with me, if you would, sir, on Demonstrative Testimony 435.

A. Yes.

Q. "QUESTION: Where did Dr. Wells get his soluble reactive phosphorus loads?

"ANSWER: Those loads were also computed by Dr. Engel.

"QUESTION: And did you review those computations?

"ANSWER: Yes.

"QUESTION: Did you review the primary data from which Dr. Engel made those computations?

"ANSWER: Yes, I did.

"QUESTION: What did you find as a result of that investigation?

"ANSWER: The SRP loads that Dr. Engel computed were also incorrect."

Now, do you agree with Dr. Bierman's testimony that I just read to you?

A. No, I don't.

Q. And would you please explain why you do not agree.

A. Well, for a couple of reasons. Dr. Engel today testified that perhaps Dr. Bierman made some mistakes in the use of the LOADEST model in computing these loads to the model. And, secondly, even if Dr. Engel made a mistake in his LOADEST model, we actually didn't use Dr. Engel's model all by itself.

Q. What did you do?

A. We used actual data when it existed.

Q. Let me show you as a matter of a demonstrative State of Oklahoma Exhibits 5406, 5409 and 5412. Do you have those before you, sir?

A. Yes, I do.

Q. Are you familiar with these three graphs?
A. Yes, I am.
Q. Where do these graphs come from?
A. These are from my expert report.
Q. Would you please explain to the court what these graphs are. I want you to maybe just generally explain what the information is, overview first.
A. These are graphs of the soluble reactive phosphorus or orthophosphorus data and what was used in the model during the calibration period for the three different systems. The Illinois River is Exhibit 5406. 5409 would be the Barren Fork. And Exhibit 5412 would be the Caney Creek.
Q. Now, for all three of these exhibits, do they use the same data as far as what -- the representation as the colors and shapes?
A. Yes. The representation of colors, for example, the purple line is what we actually used in -- as input to the W2 model. Then the discrete points are actual field data taken at that location.
Q. How does this information relate to the information you got from Dr. Engel and the work -- and the information you actually used for SRP as

inputs to your model?
A. Well, basically we received a regression line from Dr. Engel, which would be the solid line. Then we altered it to reach out and grab data points when they existed. And I can't remember exactly whether we reached out and grabbed the data points several days before and then several days after, gradually went back to the original regression line. But whenever data existed, we used that data.
Q. Now, let's assume, arguendo, that Dr. Bierman is correct, and Dr. Engel made a mistake on his regression analysis for SRP. Based on what you did, would that have a substantial or material effect on your modeling?
A. I don't think it would have made much difference in the adjustment of the particular correlation line that was used, because as we can see, the field data do tend to match that line even as it is right now.
Q. So did you use this actual data to verify the regression analysis?
A. Yes, we did. This was one of our checks.
Q. Now, Dr. Wells, I want to change topics again on you, and I want to talk to you about Dr. Bierman's opinion that assuming that Dr. Engel's

outputs were flawed for some reason, your modeling results would also be flawed.

And I would like for you to look at Demonstrative 436, Testimony Demonstrative 436 taken from Dr. Bierman's testimony. Do you have that, sir?

A. Yes, I do.

Q. "QUESTION: Doctor, based on your review of the modeling work of Dr. Wells, do you have an opinion as to whether Dr. Wells' modeling results provide a realistic and reliable representation of water quality for the lake for either current, historical or future conditions?

"ANSWER: Yes, I do.

"QUESTION: What is that opinion?

"ANSWER: The water quality computed by Dr. Wells' model for his calibration period, those results are flawed due to the flawed and unreliable inputs for total phosphorus and soluble reactive phosphorus provided to Dr. Wells by Dr. Engel...

"For all of Dr. Wells' forecast scenarios and predictions, as well as his 100-year hindcast, he used the flawed and unreliable outputs, predictions, from Dr. Engel's flawed models. Therefore, all of Dr. Wells' forecast results and

hindcast results are similarly flawed and unreliable."

Now, let's assume that Dr. Bierman is correct. Clearly the State is not conceding that by any means, but let's assume that's correct, that there was flawed total phosphorus data provided to you by Dr. Engel and flawed soluble reactive phosphorus data provided by Dr. Engel. Do you agree that that would affect -- make your models unable to predict water quality?

A. No.

Q. And why is that?

A. Well, first of all, it's quite clear that the model does represent current conditions in the lake. The cycle of stratification and oxygen depletion are quite realistic compared to field data.

Q. This was actual data that was collected by Dr. Wells -- not Dr. Wells -- Dr. Welch and Dr. Cooke validate the model, so to speak?

A. They computed some independent calculations of oxygen uptake in the hypolimnion and habitat availability for fish. And independent of their work, the model corroborated their calculations.

Q. Okay. Are there any other reasons why you

would disagree with Dr. Bierman's opinion?
A. Yes. The lake model really is independent, as was brought out during my direct testimony and my cross. It is just looking at phosphorus coming down Tenkiller -- or down the Illinois, Barren Fork or Caney Creek, and it's responding to that.
So the lake model itself is looking at how changes in phosphorus loading coming into the system affect water quality in the lake.
So it's really independent of what's happening up in the watershed. It is just looking at the response of the lake. And I think that's the big question for this court is can Tenkiller Lake be improved by reductions in phosphorus in the watershed.
Q. So regardless of whether Dr. Engel overestimated or underestimated on his scenario the potential reduction by 10 or 15 percent, does your model still have an answer for this court as to whether or not the lake would be improved if phosphorus inputs to the lake were reduced?
A. Yes. If phosphorus inputs to the lake were reduced, the model predicts, and I stand behind the result, that Tenkiller water quality would improve.
Q. What about the other side of the coin, assuming

that additional phosphorus increases to the lake, what does your water quality model of the lake indicate?

A. It would indicate that the water quality and oxygen conditions would get worse in Tenkiller Reservoir.

MR. PAGE: Your Honor, I pass the witness.

THE COURT: Given that we're not going to complete him by 5:30 -- is that a fair assumption?

MR. PAGE: I'm finished with Dr. Wells. I do not know what the cross-examination or potential redirect would be.

THE COURT: I need to know. I've got another matter that's apparently more or less an emergency that I need to address. What's the best estimate? Can we finish here by 5:30?

MR. EHRICH: I'll do my best. I think so.

MR. PAGE: This witness will be here in the morning. I'm happy to bring him back. He missed his flight. He can't make the flight now.

(Off-the-record discussion was had.)

THE COURT: We'll be in recess.

MS. MOLL: Your Honor, may I be heard? It will take one minute.

THE COURT: All right.

MS. MOLL: Forgive me, Judge.

THE COURT: Fine.

MS. MOLL: Defendants' request to put on surrebuttal testimony by Dr. Connolly was requested and granted with some dispatch. I think if they're going to request leave to put on surrebuttal by Dr. Bierman, the State would request that they, just as we did on the 13th with our proposed rebuttal, that they do the same for Dr. Bierman if they're going to pursue it.

THE COURT: Will any further surrebuttal be pursued?

MR. GEORGE: We're going to evaluate that tonight. We'll be happy to communicate that to the court and the plaintiffs as soon as we have consensus on our side, but I cannot do that at this moment.

THE COURT: Please.

MS. MOLL: That's fine. As was done with respect to the State when we were required to do so, we had a limited number of hours to put that together, and I guess I would ask for the goose-gander rule to be invoked here.

THE COURT: Absolutely. Of course, this is a slightly different scenario. But by what time

could that be done, in all fairness?

MR. GEORGE: By 8:00 this evening.

MS. MOLL: That will be fine.

THE COURT: Let's do that. By the way, I like the fact that the Doctor can actually spell Barren Fork correctly.

(End of proceedings.)

REPORTER'S CERTIFICATE

I CERTIFY THAT THE FOREGOING IS A TRUE AND CORRECT TRANSCRIPT OF THE PROCEEDINGS IN THE ABOVE-ENTITLED MATTER.

S/Terri Beeler
Terri Beeler, RMR, FCRR
United States Court Reporter